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ANGIOCARDIOGRAPHIC DETERMINATION OF LEFT VENTRICULAR VOLUME

by

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Determination of total cardiac volume by the conventional technique has long been part of the routine roentgen examinations of the heart, at least in Scandinavia. ROHRER (1916) was the first investigator to use the sagittal measurements of the heart and not merely its surface in the frontal projection for volume determinations. KAHLSTORF (1932, 1938) elaborated ROHRER's method, and assumed that the heart was shaped as a combined ellipsoid and paraboloid. The frontal surface of the heart was determined with the aid of an orthodiagram and the greatest depth was also measured orthodiagraphically. According to the ROHRER-KAHLSTORF formula, the cardiac volume was $0.63 \cdot Fa \cdot L_{max}$, where Fa is the frontal surface and L_{max} the greatest sagittal measurement. Methods based on a three-dimensional conception of the heart have also been devised by CIGNOLINI (1928), BOLLINI (1935) and BENEDETTI (1936).

The fact that the geometric magnification need not be taken into consideration with the orthographic technique is an advantage but, on the other hand, the method is time-consuming and exposes the patient to considerable radiation hazards.

LILJESTRAND, LYSHOLM, NYLIN and ZACHRISSON in 1939 published a modification of the ROHRER-KAHLSTORF method, by which the volume of heart as an ellipsoid was calculated. They used teleroentgenography instead of orthodiagraphy, and introduced a correction factor for the geometrical magnifica-

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tion. This method was further modified by JONSELL (1939) who demonstrated that in place of the three theoretical ellipsoid axes three readily identifiable diameters in the heart can with very slight error be employed for measuring the volume. With this method the cardiac volume is $0.42 \cdot l \cdot b \cdot d$, where l, b and d are the three axes. The factor 0.42 is calculated for a film-focus distance of 1.5 m, both for frontal and lateral projections; it is only applicable for adult patients with normal body dimensions.

With the development of the angiocardiographic technique it has become possible to make intra vitam studies of the volumes of the different heart chambers. The right atrium and ventricle are both so irregularly shaped that it is difficult to find any satisfactory method of determining their volume with the use of two orthogonal projections. The left atrium and ventricle, on the other hand, are fairly regular in shape and hence lend themselves better to volume analysis. Measurement of left atrial volume has been carried out both by cineangiography (GRIBBE et coll. 1958, 1959, 1960), and with an ordinary film changer (ARVIDSSON 1958, SOLOFF et coll. 1956, 1957).

Two different methods have primarily been employed for measurement of the volume from two projections at right angles, namely (1) planimetric determination of the surface in one or two projections and (2) a determination assuming that the body to be examined has a definite geometric shape and hence using for the measurement certain fixed diameters from which the volume can be calculated. With both these methods several assumptions and approximations must be made. As was shown earlier (ARVIDSSON 1958), not even with a geometrically defined ellipsoid can the volume be determined with the aid of two orthogonal projections if the orientation of the axes is not known. An advantage of the planimetric method of volume measurement is that it permits a volume determination even in the case of a fairly irregular body; but on the other hand the outer contours of the body, whose volume is to be determined, must be wholly defined in the two projections used, a feature seldom occurring at angiocardiography. With a volume determination based on three diagonal measurements and assuming the body to be a regular ellipsoid, there is no necessity for the outer contour to be distinguishable in its entirety; the only points that need be identified are those determining the axes of the body. The latter method of measuring volume can be fairly easily carried out and thus is suitable for routine work.

As regards the choice between cineangiography and an examination with an ordinary film changer, the cine method certainly has the advantage of allowing a high exposure rate; the films obtained however are often of such poor quality, at least in adult patients, that determinations are not easy to carry out. A film changer produces good quality views and the measurements can be carried out directly on the films without the necessity of enlargement. The relatively low exposure rate is, of course, a disadvantage when rapidly changing volumes and haemodynamic occurrences are to be studied.

As the present writer has previously demonstrated, it is possible to obtain an approximate value for the volume of the left atrium in man, especially when the chamber is dilated as in mitral disease. When dilated, the atrium assumes the shape of an ellipsoid and hence its volume may be measured from the three principal axes of this ellipsoid. While a knowledge of the volume and volume variations in the left atrium is valuable in helping us to understand the haemodynamics of the left side of the heart, it is even more important to be able to calculate volume variations in the left ventricle. Measurement of left ventricular volume is however much more difficult to carry out than a left atrial determination. CHAPMAN, BAKER, REYNOLDS and BONTE (1958) made left ventricular volume studies in the dog and in man with the aid of biplane cinefluorography. They started by using Simpson's parabolic formula for determination of the volume of irregular bodies. As this method is very time-consuming they subsequently changed over to an empirical formula based on experiences from volume measurement by Simpson's method. The empirical method they used was based on a planimetric determination of the ventricular area in two projections at right angles. If the product of the two surface projections of the ventricle is X and the volume is Y, then $\log Y = -0.4444 + 0.8216 \log X$.

GRIBBE, HIRVONEN, LIND and WEGELIUS (1959) also applied cineangiography for determination of left ventricular volume in the dog. Using planimetric measurement as well as measurement of the axis lengths in the ventricle they found very little difference between the two methods and thus chose the latter technique for their subsequent volume studies. These authors also corrected for papillary muscles and trabeculae carneae by determining the volume of these tissues at autopsy and then subtracting this intracavitary muscular volume from the estimated ventricular volume. GRIBBE (1960) later made a comparison between a minute volume determination by the Fick method and by angiocardiography in dogs and cats and obtained good agreement between the two methods.

Equipment and Methods

A GIDLUND (1956) biplane film changer allowing exposure of 6 pairs of films per second was used at all examinations with a 6-valve Elema Triplex Automatic 1 000 CE apparatus with a maximum voltage of 140 kV as generator. The contrast medium employed throughout was Urografin® (Schering) 60 % containing 290 mg of iodine per ml and it was injected with a GIDLUND injection syringe. In order to localize the exposures in the heart cycle ECG tracings, with simultaneous recording of exposures and injection, were made with an Elema four-channel Mingograph as the electrocardiographic apparatus. The minute volume was calculated with an oxygen breathing spirograph manufactured by AB Instrumenta, Lund, Sweden.

Projections. True antero-posterior and lateral projections were used at all examinations, partly because these are suitable for left ventricular measurement and partly because exactly the same projections may be readily reproduced in the event of a renewed examination, possibly postoperatively, at a later date.

Exposure data. The examinations were made on adult patients and the exposure data were as follows:

	kV	mA	sec
A. p. projection	90 to 120	300	0.01
Lateral projection	90 to 120	200 to 300	0.01

As both tubes were driven by the same generator, kilovoltage and exposure time were the same in both projections. Variations in density in different patients were compensated for by altering the tube voltage.

Determination of minute volume by the Fick method. The oxygen consumption was recorded with a spirograph while the patient was breathing 100 per cent O_2, and at the same time the arteriovenous oxygen difference was measured in samples taken simultaneously from the pulmonary and brachial arteries. The oxygen saturation in the samples was determined by the van Slyke technique. In a few cases, duplicate determinations were carried out and these showed that the method possesses good reproducibility. This minute volume determination was made 15 to 30 minutes before the angiocardiography. The heart rate was measured during the determination so that the stroke volume could be ascertained in cases with regular sinus rhythm.

Roentgenographic demonstration of the left ventricle

In the main, two different methods were used for demonstrating the left ventricle.

1. *Contrast medium injection into the pulmonary artery.* After the usual catheterization of the right heart, with pressure recording, blood-gas analysis, and minute volume determination by the Fick method, a No. 9 or 10 USCI catheter with side holes was manoeuvered so that its tip lay in the main pulmonary artery. General anaesthesia was then achieved in accordance with the following scheme:

A. 35 to 50 mg meperidine, intravenously
B. 100 to 150 mg sodium pentothal, intravenously
C. About 50 mg succinylcholine iodine, intravenously
D. Endotracheal intubation with a cuff tube
E. Maximum oxygenation of the patient
F. Injection of the contrast medium while the anaesthetist kept the intrapulmonary pressure at a low level (0 to 5 mm Hg); while the medium was being injected 6 to 9 pairs of films were exposed in order to allow a study of the pulmonary blood vessels
G. When the medium was estimated to have passed through the lungs the intrabronchial pressure was slowly raised to about 20 mm Hg by oxygen inflation.

The time usually required for the contrast medium to pass through the lungs is between 3 and 6 seconds, depending on the cardiac volume and the pressure in the pulmonary circulation; the greater the cardiac volume and the higher the PA and PCV pressures the slower is the passage of the medium through the lesser circulation. In conjunction with the raising of the intrapulmonary

pre ure a series of films were taken, with 6 exposures per second, during con st-filling of the left side of the heart. This final exposure phase lasts about 5 se nds. For injection into the pulmonary artery 1.3 to 2 ml of contrast medium per kg of bodyweight and an injection rate of 20 to 40 ml per second were used.

This method has proved valuable for the study of the left atrium, mitral orifice, left ventricle, and aorta (ARVIDSSON). In cases with considerable dilatation of the left heart the concentration of contrast medium in the left ventricle is sometimes so low that the outlines of this chamber are difficult to distinguish in the films. The method has two advantages, first that it is relatively risk-free, and secondly that disturbances in the heart rhythm seldom occur during the roentgenographic phase in which the left ventricle is visible; this is a valuable factor for the construction of volume curves (see a later section).

2. *Contrast medium injection into left ventricle.* In several cases the contrast medium was injected directly into the left ventricle after retrograde arterial catheterization from the right radial artery. This method as well as its range of application has been described by HANSSON, JÖNSSON and KARNELL (1959). This examination also is begun with right heart catheterization, a pressure recording, and a minute volume determination by Fick's method. The right radial artery is then exposed, and a No. 9 or 10 side hole catheter is inserted into the aorta, where a pressure recording is made. The catheter is then passed through the aortic orifice into the left ventricle and the pressure is recorded again. Pressures are then recorded while the catheter is withdrawn, to demonstrate if there is a systolic gradient over the aortic orifice, in other words whether there are signs of aortic stenosis. In order to confirm any clinical suggestion of aortic insufficiency a small amount of contrast medium (30 to 40 ml Urografin 60 %) is injected into the ascending aorta in these cases. During the injection, 6 to 9 pairs of film are exposed at a rate of 3 exposures per second. This part of the examination is carried out without general anaesthesia. Immediately after this aortography, the catheter is again passed down into the left ventricle and general anaesthesia is produced in the same way as already described under points (A) to (E) in connection with the pulmonary artery injection. With the left ventricle injection method, the intrapulmonary pressure is kept at a fairly high level (about 20 mm Hg) from the beginning. An amount of 0.8 to 1 ml Urografin 60 % per kg of bodyweight is injected at a rate of 25 to 30 ml per second. During and after the injection, 6 pairs of films per second are exposed in antero-posterior and lateral projections over a period of about 4 seconds. This technique gives a complete angiocardiographic picture of mitral and aortic disease, and it has been found that the left ventricle can be reached even in cases with relatively severe aortic stenosis.

The method has two drawbacks. In the first place, with the method we have used it is necessary to sacrifice a radial artery. In all probability, however,

it should be possible to catheterize the left ventricle after percutaneous puncture of the femoral artery, at least in cases with no aortic stenosis. In the second place, when contrast medium is injected into the left ventricle extrasystoles often occur during the actual injection. The heart usually returns to its normal rhythm after only a few abnormal beats, however. A whole series of extrasystoles sometimes occur during the examination and prevent satisfactory measurement of the left ventricular volume and, in isolated cases, sinus tachycardia may reduce the possibilities for volume determinations.

Material

The purpose of the present work was to study the possibility of making angiocardiographic left ventricular volume determinations with clinically satisfactory accuracy. Selected cases were therefore taken from among the extensive angiocardiographic material in the department. The material consists for the most part of acquired lesions not involving demonstrable incompetence in either the mitral or aortic orifice; nor were there signs of shunt in any of the cases. As the angiocardiographic technique has shown itself to be relatively risk-free the indications for the examination have gradually been widened, and the material contains patients with sound hearts with only a vague suggestion of cardiac disease. As already mentioned, a number of cases were rejected, for the following reasons:

1. A minute volume determination by the Fick method had not been performed, or had been unsuccessful. As this form of minute volume determination came into use as a routine measure in the department in 1958 all older cases consequently had to be rejected.
2. Fibrillation or other severe disturbance of rhythm had been present during the examination; this prevented determination of the stroke volume. A few cases with regular fibrillation rhythm were included.
3. Unsatisfactory electrocardiographic and exposure recording during the examination prevented determination of the position of the films in the heart cycle.
4. Because of unsatisfactory roentgenographic demonstration of the left ventricle adequate volume measurement was not possible.
5. The exposures occurred at such unsuitable positions in the heart cycle that none of the views showed maximum systole and diastole.

The material was thus reduced to 16 cases. In 9 cases the contrast medium was injected into the pulmonary artery and in 7 cases directly into the left ventricle after retrograde catheterization. It may be pointed out that a satisfactory angiocardiographic diagnosis was also obtained in the rejected cases even though they could not be used for the special purpose of measuring the left ventricular volume variations.

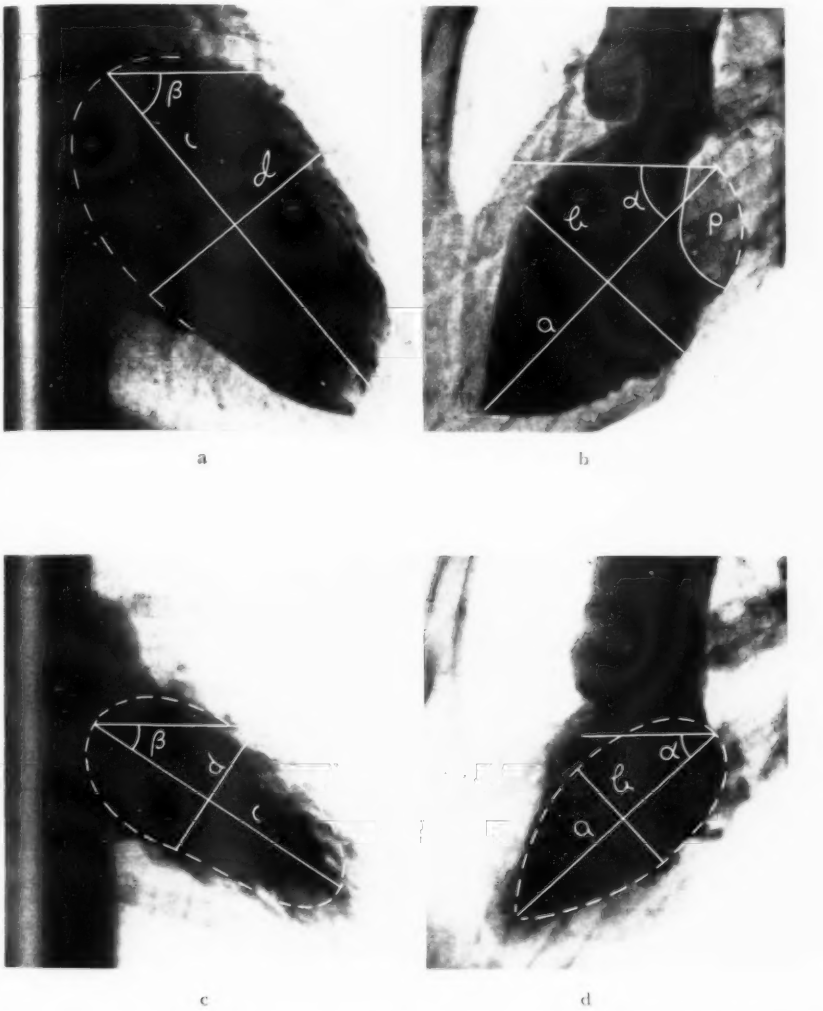
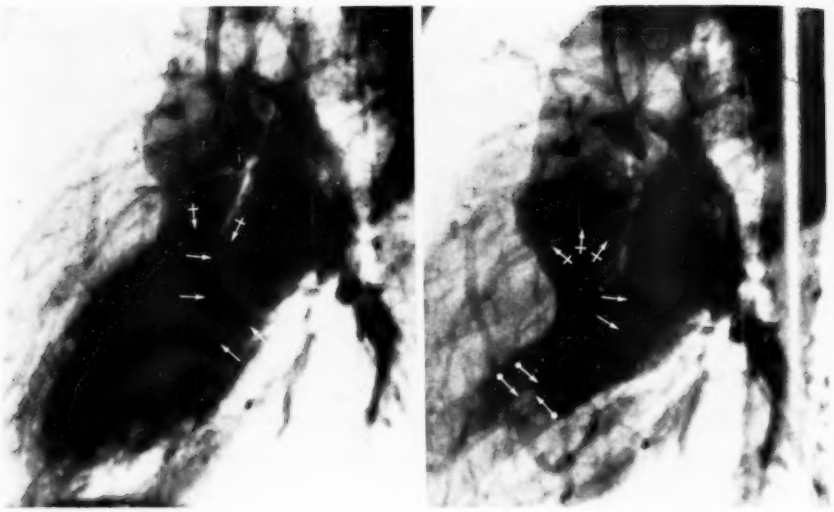


Fig. 1. Method of left ventricular volume determination. Left ventricular contrast medium injection in a case of mitral stenosis and aortic incompetence. (Case not included in this material.) a) A. p. projection at end of diastole. Top of ventricular ellipsoid completed. Pouch formed by ballooning mitral leaflets can be traced in left upper part of left ventricle. Axes of ellipsoid are drawn. b) Lateral projection in same heart phase as (a). Pouch formed by mitral leaflets (P) clearly defined. Papillary muscles partly visible. c) A. p. projection at end of systole. Top of ellipsoid is not easy to identify. d) Lateral projection in same phase as (c). Top of left ventricular ellipsoid is formed mainly by the anterior mitral leaflet. Papillary muscles included in the volume determination.



a b

Fig. 2. *Case 1.* 'Athlete's heart'. No signs of heart disease. Pulmonary artery contrast medium injection. Films exposed during filling of left side of heart. a) Lateral projection, end of diastole. Small left atrium. Mitral leaflets partially visible (→). Top of left ventricular ellipsoid can be traced (↔). b) Lateral projection, early phase of diastole. Left atrium slightly larger than in late diastole. Mitral valve is beginning to open (→). Aortic cusps closed (↔). No trabeculation visible in left ventricle. Papillary muscles clearly defined (→). Determination of actual top of left ventricular ellipsoid is difficult.

In the cases selected, all measurable pairs of films were subjected to volume calculation, and where possible a volume curve was constructed as well. To avoid bias, the stroke and minute volumes were calculated without previous knowledge of the result of the Fick minute volume determination. The most important data relating to the material are given in the table on pp 334–335. It does not include the results of clinical examinations and operations, but only a summarizing diagnosis based on clinical and angiocardiographic findings and in some cases on the results of operation.

Calculation of left ventricular volume

In an earlier publication (1958) the present writer described the principles for volume measurement when the left ventricle is regarded as an ellipsoid. Since that date, however, the method has been further developed and simplified. In both frontal and lateral projections, it may be observed that in diastole the left ventricle is more or less elliptical in shape (see Figs 1a, 1b, and 2a). In the frontal projection the long axis of the ellipsoid makes an angle usually of between 45° and 55° with the horizontal plane (see Fig. 1). The angle be-

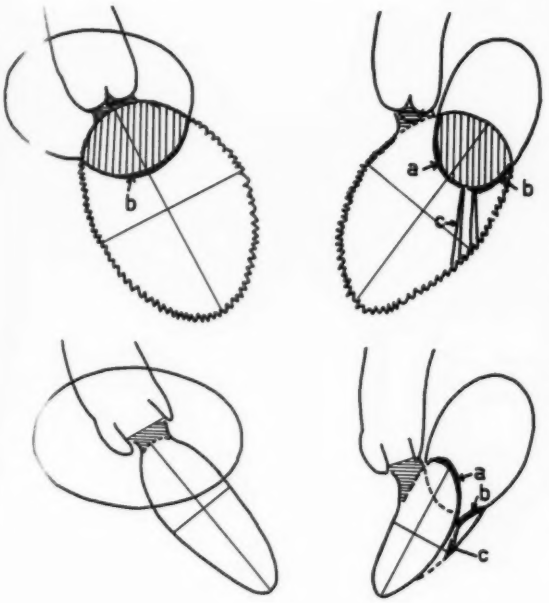


Fig. 3. Schematic illustration of details to be considered in the determination of the left ventricular volume especially in mitral stenosis.

Top left and right: A.p. and lateral projections in diastole. Anterior mitral leaflet (a); posterior leaflet (b); papillary muscles (c). The points of measurement are set in the middle of the trabeculation. The part shown with vertical lines must be deducted from the volume of the ellipsoid. Part with horizontal lines is not included in the volume determination.

Bottom left and right: A.p. and lateral projections in systole. Symbols the same as above. Trabeculation not visible, points of measurement are set at outer borderline of ventricular ellipsoid. Papillary muscles are included in the volume, i. e. the short axis on the lateral projection is drawn to the posterior part of the papillary muscle contour. As in diastole the subaortic volume (horizontal lines) is not included in the volume determination.

tween the long axis and the horizontal plane in the lateral projection is generally slightly larger but is seldom greater than 60°. The ventricular ellipsoid is as a rule slightly more pointed towards the heart apex than at the base; in other words, it may be said to consist of an upper semi-ellipsoid with a slightly lesser degree of eccentricity, and a lower one with slightly greater eccentricity. This fact does not influence the volume determination, as the volume of two united semi-ellipsoids with a common contact surface may be calculated by the same method as that used for a regular ellipsoid. The factor of greatest significance to the volume measurement is that the two short axis projections in the frontal and lateral projections (*d* and *b*) respectively should always be of approximately the same length. This applies to all parts of the heart cycle. It means that a section through the ventricle in the plane through the two short axes will be practically circular, or in other words that the ventricular ellipsoid is nearly a rotation ellipsoid. The ventricle is more irregular in maximum systole than in diastole (see Figs 1c, 1d and 2b), and the accuracy of a systolic volume determination is of a much lesser degree than that of the corresponding diastolic value. As the main purpose of the method is to determine the stroke volume a percentage error in the determination of the end-systolic volume is of relatively less importance than an error in the diastolic volume.

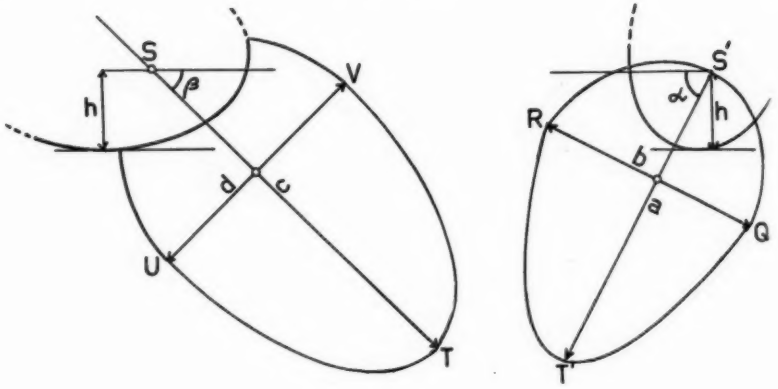


Fig. 4. Diagrammatic illustration of the construction of the top of the left ventricular ellipsoid *Left:* A.p. projection showing visible part of left ventricle and bottom of left atrium. *Right:* Lateral projection showing the same details as in the left figure. Height difference, *h* mm, from bottom of left atrium to top of left ventricle (*S'*) is transferred from the lateral to the antero-posterior projection. At the point where the horizontal line *h* mm above bottom of left atrium in antero-posterior projection cuts the long axis projection the top of the ellipsoid is situated (*S*).

In mitral stenosis, the ballooning mitral cusps appear in diastole as a defect in the upper portion of the ventricular ellipsoid (see Figs 1a, 1b and 3). This volume must be regarded as belonging functionally to the atrium as the blood contained between the cusps at the close of diastole will be returned to the atrium at the opening of systole, when the leaflets are thrown back toward the atrioventricular plane (see Figs 1d and 3). Geometrically, the 'balloon' belongs to the left ventricle and consequently the volume of this part must be deducted from that of the ventricular ellipsoid. The volume of the space between the mitral valves was calculated partly as an ellipsoid and partly as two segments of a sphere. The difference between these two methods of calculation is very small, and the simplest method is to calculate the volume as an ellipsoid. The volume of this space varied from 10 to 30 ml. In systole, correction for the volume above the mitral valves need not be made when mitral stenosis is present, as during this heart phase the leaflets are thrown upwards and backwards toward the atrioventricular plane and form the upper pole of the ellipsoid (see Figs 1d and 3).

When no mitral stenosis is present, the mitral leaflets are difficult to distinguish and correction for the volume between them cannot be made. This volume is very small, however, when the mitral leaflets are normal, as they approach each other at the end of diastole. The blood immediately under the aortic valves (see Fig. 3) will not be included in the volume of the ventricular ellipsoid. This space is readily identifiable in the lateral view but not in the frontal view, and

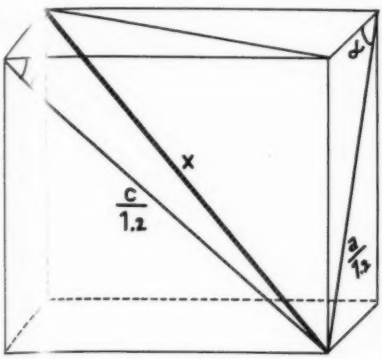


Fig. 5. Determination of long axis of left ventricular ellipsoid from the two orthogonal projections, which have been corrected for the magnification by dividing by 1.2.

hence the volume cannot be calculated satisfactorily. This part of the ventricle, however, does not undergo any appreciable changes during the heart cycle. As it is only slightly larger in systole than in diastole it is of little significance in the calculation of the left ventricular stroke volume. However, owing to the fact that the subvalvular space is not included in the calculation the values for both the maximum and minimum, ventricular volumes will be slightly too low.

The papillary muscles and trabeculae carneae in the left ventricle constitute another problem in volume measurement. As already mentioned, GRIBBE et coll. (1959) solved this problem in experiments in dogs by determining the volume of these areas of muscle tissue by making models. This method is not applicable in man when pathologic conditions are present, as the volume, particularly in the case of the trabeculae carneae, is subject to considerable variations according to the degree of left ventricular hypertrophy. The papillary muscles are of little significance in an estimation of the stroke volume, as their volume is the same both for end-systolic and end-diastolic volume calculations (see Figs 1 d and 3). The error arising through inclusion of the papillary muscle volume in the ventricular volume will counteract the error caused by the non-inclusion of the subaortic space in the calculation. The volume of the trabecular network presents a more difficult problem. During the periods of the heart cycle in which the ventricle is of large volume its outer contour is visible at the outer portion of the trabeculation; in other words, if the ventricular volume is calculated on the basis of the outermost contour, the trabeculae will also be included in the measurement. This would not be of much significance if they were also included in the calculation for the heart phases in which the ventricle is small, i. e. at the close of systole. This is not the case, however, as the blood between the trabeculae is pressed out at ventricular contraction and the outer contour of the left ventricular cavity is formed by the inner surface of

Fig. 6. *Case 2.* Left ventricular volume curve constructed by plotting together volume determinations from different heart cycles. Maximum volume at QRS, minimum volume at end of T-wave. In midphase of systole, slightly slower ejection. No 'rapid' and 'reduced' ventricular filling during diastole but immediately before atrial systole a slight decrease in the filling speed.

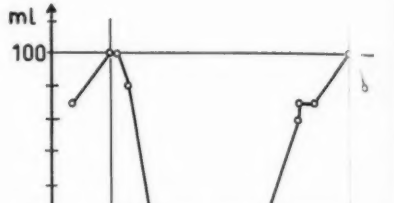


Fig. 7. *Case 11.* Left ventricular volume curve constructed as in fig. 6. Few points of measurement during ejection. Small indentation during diastole before left atrial contraction.

the trabecular network (see Fig. 3) so that the trabeculation will not be included in the ventricular volume at a determination made in the closing phase of systole.

The simplest method of compensating satisfactorily for this error is to move in the points of measurement in the roentgen views for a distance equal to half the thickness of the trabecular network. This applies only to those views which have been exposed during the phases in which the ventricular volume is large; the thickness of the trabeculation can then as a rule be seen in the films.

Volume measurement in practice

As may be seen from Fig. 4, the points U, V, R and Q can readily be defined, and the lengths of the two short axis projections *b* and *d* may thus be determined after the thickness of the trabeculation has duly been taken into consideration. The points T and T′ on the antero-posterior and lateral projections respectively are as a rule also easy to identify. S′, which is situated between the mitral and aortic orifices, is usually obtained direct, but in some cases it is necessary to complete the upper part of the ellipse by continuing the outline of the ventricular ellipsoid upwards. It is much more difficult to place the point S in the frontal projection, and this can often not be done without an auxiliary construction. It is known that the points S and S′ in the two projections must lie at the same horizontal level. If the level of S′ has been determined in the lateral projection

it ca be transferred to the frontal projection if a reference level identifiable in both projections is available. One such level that is usable is the lower border of the ft atrium, if this chamber has been demonstrated by injection of contrast medium into the pulmonary artery; the radiopaque metal tip of the heart catheter is another excellent reference point in the case of injection into the left ventricle. Fig. 4 will serve as an illustration of this. The point S′ was obtained through the completion of the 'lateral ellipse'. The difference in height between the lowermost portion of the left atrium and S′ is h mm. In the frontal view the lower tangent is drawn to the left atrium and a horizontal line is drawn parallel to this line h mm above it. At the point where the upper line meets the longitudinal axis of the frontal ellipse the upper pole of the ellipse will be situated in the frontal projection. The longitudinal axis of the ellipse is constructed by finding the centre point on the transverse axis and drawing the line from the apex out through this centre point. In this way the length of the axis projections may be determined from the long axis in the ellipsoid.

To make further progress with the volume determination, it is necessary to know the geometric magnification in the two projections. For the centre of the ellipsoid, the magnification in both projections is, with the apparatus used, approximately 1.2. This is applicable in adult patients, in whom the difference in magnification between different individuals is negligible. This means that the two short axes in the ellipsoid are $b/1.2$ and $d/1.2$ respectively. Stereometry must be used in the calculation of the long axis x. In Fig. 5 the frontal and lateral projections of the long axis x have been traced in a parallelepiped after correction for the magnification. It will be found from this figure that

$$x^2 = \frac{a^2}{1.2^2} + \frac{c^2}{1.2^2} \cdot \cos^2\beta$$

$$\text{or } x = \frac{1}{1.2}\left(a^2 + c^2\cos^2\beta\right)^{1/2}$$

By this procedure the long axis is calculated solely with the assistance of the lengths of the two projections in the frontal and lateral views and the angle formed by the axis projection with the horizontal plane in the a. p. projection. The reason for this method of calculation is that the most difficult axis projection to determine, i. e. axis c, is multiplied by a factor $\cos^2\beta$, which is of the order of magnitude of 0.33 to 0.50; hence the possible error arising in the measuring of c will be reduced. According to the formula for the volume of the ellipsoid, the total ventricular volume will be

$$\frac{4\pi}{3} \cdot \frac{1}{1.2 \cdot 2}\left(c^2\cos^2\beta + a^2\right)^{1/2} \cdot \frac{b}{1.2 \cdot 2} \cdot \frac{d}{1.2 \cdot 2}$$

$$\text{or } 0.3\, b\, d\left(c^2\cos^2\beta + a^2\right)^{1/2}$$

Table

Case No.	Patient	Age	Sex	Diagnosis	Heart volume		Site of contrast injection	L. V. end diastolic volume ml	L. V. end systolic volume ml	L. V. stroke volume ml
					total ml	ml/m² B. S. A.				
1	S. J.	17	M	Athlete's heart	850	530	PA	105	15	90
2	E. B.	60	F	Pericardial diverticulum + art.hypertension	[1](1 060)	[1](620)	PA	100	15	85
3	L. L.	14	M	Right sided aortic arch.	400	260	PA	60	20	40
4	B. T.	19	M	Juvenile art. hypertension	690	370	PA	130	20	110
5	M. K.	24	F	Patent ductus postop. exam.	790	570	LV	80	30	50
6	B. T.	23	F	Coarctation of the aorta	580	350	LV	50	10	40
7	Å. A.	27	M	Coarctation of the aorta	770	420	LV	90	40	50
8	K. G.	43	M	Subaortic stenosis	1 090	550	PA	80	25	55
9	I. S.	33	F	MS	700	420	PA	95	30	65
10	M. C.	53	F	MS	820	550	PA	140	25	115
11	S. H.	49	F	MS	780	510	PA	100	5	95
12	R. M.	18	M	MS	960	450	PA	95	25	70
13	S. L.	35	F	MS	910	560	LV	145	45	100
14	M. B.	33	F	MS	590	380	LV	70	20	50
15	J. D.	47	M	MS + AoS	1 130	630	PA	130	50	80
16	S. A.	58	F	MS + AoS	980	430	LV	90	25	65

[1] Diverticulum included in heart volume. — [2] Double Fick determination. Abbreviations: AoS—Aortic stenosis, L. V. — Left ventricle, MS — Mitral stenosis, PA — Pulmonary artery.

In the present work all diameters were measured with an accuracy of 2 mm and the volumes obtained were abbreviated to the nearest 5 ml value. The angle β was rounded off to the nearest degree evenly divisible by 5.

Control of accuracy of measurement method. If the ventricular volume is determined at the end of systole and the end of diastole a value may be obtained for the stroke volume of the left ventricle during the angiocardiographic examination. As the heart rate during the examination is known from the simultaneous ECG and exposure recordings, it is possible to determine the minute volume of

Heart rate during angiocardiography	L. V. minute volume angiocardiographic L.	Minute volume Fick determ. L.	Heart rate during Fick determ.	Difference Fick-angio minute-vol, in % of Fick value	Left ventricular volume curve	Pressure				
						PA S/D	PA Mean	PCV Mean	L. V.	Ao
7[illegible]	6.8	6.2	80	10	+					
7[illegible]	6.4	4.2	76	50	+	23/8.5	14	6		
135	5.5	6.5	90	15	—	11/2	6.7	3		
110	12.1	13.2	80	8	—	30.5/12.5	21	13	—	170/90
140	7.0	5.8	62	20	—					
160	6.4	6.5	66	1.5	—	29/8	14	10	173/0—6	208/119
175	8.8	8.6	88	2	—	17/5	12.5	6.5	150/0—4.5	148/98
75	4.1	3.8	62	8	—	31.5/14.7	21	14		
130	8.5	8.8	95	3.5	—	35/17	27	20		
45	5.2	4.7	70	6.5	—	34/10	19	14		
85	8.0	7.2	72	11	+	46/22	33	26		
115	8.0	[2]7.3, 7.0	[3]61, 66	12.5	—	27.5/7	17	14.5		
64	6.4	6.1	50	5	+	26/9	14	9	100/2.5—9.5	100/49
135	6.8	7.1	8	4	+	43/21.5	29.5	20	117/1.5—7.5	125/67
90	7.2	7.1	85	1.5	—	26/12	18	11		
130	8.5	6.2	68	35	—	30/6	17	9.5	131/0—8	115/57.5

the heart under the prevailing conditions. A minute volume determination by the Fick method was carried out in order to ascertain the relation of these values to the true resting minute volume. In most of the cases (see Table) there was fairly good agreement between the two determinations, especially when it is remembered that even the Fick minute volume determination is considered to be handicapped by an error of $\pm$ 10 %.

In those cases in which the rhythm is regular during the angiocardiography, and which have yielded a number of films with a clearly defined left ventricle, the measurement results from different heart cycles may be combined to form

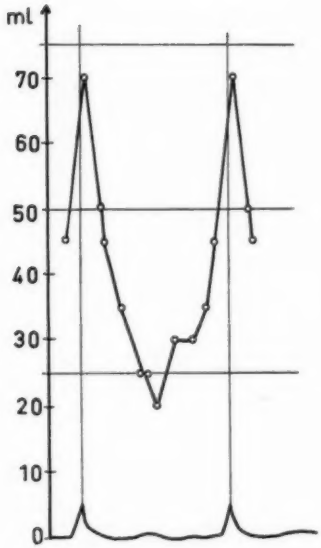


Fig. 8. *Case 14.* Left ventricular volume curve. Tachycardia during examination, 135 strokes per min. Evacuation of ventricle very rapid during early systole. Diastole is short and most of the ventricular filling takes place during atrial systole.

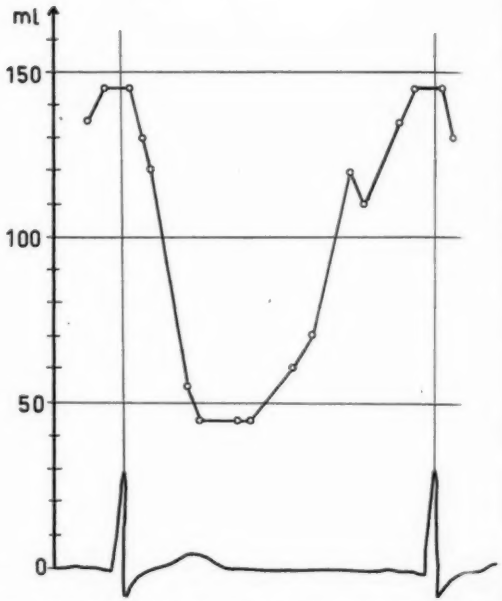


Fig. 9. *Case 13.* Left ventricular volume curve. Relatively slow heart rate during examination. No exposure obtained at QRS and maximum volume is probably lacking. During late systole the curve is flattened. Note indentation in diastole before P-wave.

a volume curve (LVC) giving a graphical representation of how filling and evacuation of the left ventricle takes place during the heart cycle. Curves obtained from the material have been included in order to demonstrate that the method of measurement is sufficiently accurate to produce a satisfactory curve and that views from different cycles in the same heart phase give approximately the same volume values (see Figs 6 to 9).

These volume curves, which will not be discussed in detail here, are of great interest from the theoretical haemodynamic standpoint. It is possible to obtain information from them regarding variations in ejection rate in different phases of systole. By determination of the cross-section of the aorta, which is easy to carry out with angiocardiography, a value for the velocity of the blood flow in the ascending aorta may be obtained. It is also possible to study how left ventricular filling is affected by mitral stenosis and by atrial systole.

Construction of a pressure-volume diagram for the left ventricle. A diagram illustrating the volume/pressure conditions in the left ventricle may be drawn

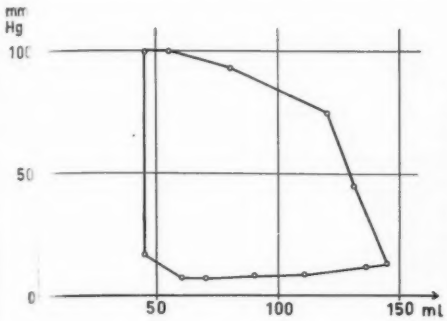


Fig. 10. *Case 13.* Pressure-volume diagram constructed from the volume curve in fig. 9, and the pressure curve from left ventricle recorded before angiocardiography. Systole begins at bottom right. First part, early systole: large pressure increase, small volume decrease. Second phase of systole: small pressure increase, large volume decrease. Top left, end of systole. Vertical line to the left: isometric relaxation. Bottom line: volume increase during diastole, very slight pressure increase. Integrated area within 'left ventricular working line' corresponds to 0.93 joule.

for those cases from which a left ventricular volume curve has been obtained, and when a pressure curve from this ventricular chamber, taken at the same heart rate, is also available. Owing to the fact that in most of our cases the rhythm was different at the pressure recording and at angiocardiography, only two such diagrams could be made. Naturally, the ideal procedure would be to carry out the pressure recording and angiocardiography simultaneously, but this involves considerable technical problems. A pressure diagram from our Case 13 is shown in Fig. 10. It is possible from such a diagram to obtain a relative value for the volume pressure work of the left ventricle by integration of the area within the working line (cf. KATZ). This method is still at the experimental stage.

Discussion

The method described for angiocardiographic determination of left ventricular stroke volume is intended to be usable for quantitative calculation of the degree of mitral or aortic insufficiency, a subject to be discussed in a future publication. In order to assess the applicability of the method a material of patients without insufficiency of the mitral or aortic orifices was assembled for the present work.

As seen from the description of the procedure, the angiocardiographic examination takes place under completely unphysiologic conditions. Although such factors as general anaesthesia, increased intrabronchial pressure, and injection of contrast medium are introduced, it has been found that a fairly good agreement exists between an angiocardiographic minute volume determination and one carried out by the Fick method; this applies even if the rhythm at angiocardiography is much higher than at a Fick determination. From this it is evident that the increased cardiac rate at angiocardiography is not due to an increased venous return, as if this were so the minute volume would be increased. The volume curves that could be made for the left ventricle to some extent

provide new aspects on left ventricular filling and evacuation. In general it may be said that the curves are not suitable for a study of small details, owing mainly to two factors, namely that a continuous course has been recorded with a discontinuous method, and that the error of the method is too great to permit definite conclusions to be drawn from small irregularities in the curve. However, the volume maximum can always directly be connected with the QRS-complex in the electrocardiogram. The volume minimum is situated approximately at the end of the T-wave, and as a rule there is a plateau at the close of systole. An important practical conclusion may be reached from these observations, namely, that for the calculation of the stroke volume it is only necessary to determine the volume from two pairs of films, one pair exposed at the QRS complex and the other at the end of the T-wave. This means that in routine determinations of the stroke volume the work can be carried out relatively rapidly without time-consuming measurement of the whole series of films.

SUMMARY

Biplane angiocardiography was used to determine left ventricular volume in different phases of the heart cycle. The stroke volume in the left ventricle was determined from the maximum and minimum left ventricular volumes, and the minute volume during angiocardiography was then determined from the stroke volume and cardiac rate. The minute volume determinations at angiocardiography and by Fick's technique were compared.

ZUSAMMENFASSUNG

Die biplane Angiokardiographie ist zur Bestimmung des linken Herzkammervolumens in verschiedenen Phasen des Herzzyklus benutzt worden. Das Schlagvolumen des linken Ventrikels wurde aus dem höchsten und dem niedrigsten Volumen bestimmt. Danach wurde das Minutenvolumen während der Angiokardiographie aus dem Schlagvolumen und der Frequenz der Herzkontraktionen bestimmt. Die Bestimmungen des Minutenvolumens bei der Angiokardiographie und mit der Fick-Technik wurden miteinander verglichen.

RÉSUMÉ

L'angiocardiographie bidirectionnelle a été utilisée pour déterminer le volume du ventricule gauche à différentes phases du cycle cardiaque. Le volume systolique du ventricule gauche a été déterminé d'après les volumes ventriculaires gauches maximum et minimum, et le débit par minute au cours de l'angiocardiographie a été déterminé à partir du volume systolique et du rythme cardiaque. Les mesures du débit par minute obtenues par angiocardiographie et par la technique de Fick ont été comparées.

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INGUINAL AND PELVIC LYMPHOGRAPHY

A preliminary report

by

W. A. FUCHS and G. BÖÖK-HEDERSTRÖM

The roentgenographic demonstration of the lymphatic system has been increasingly used in recent years as a method of detecting malignancy in lymph nodes.

TJERNBERG (1956) studied in animals experimentally induced inflammatory changes and tumor metastases in lymph nodes. FISCHER & ZIMMERMANN (1959) investigated tumor simulating lesions and inflammatory reactions, produced artificially in the lymph nodes of animals, by means of lymphography. COLLETTE (1958) presented the first and up to then the largest clinical study of human subjects with cancer metastases in the pelvic lymph nodes investigated lymphographically. KAINDL et coll. (1958, 1960) believed they found characteristic roentgenographic changes in lymph nodes for different types of malignant tumors. MALAMOS et coll. (1959) described structural changes in malignant systemic diseases of the lymph nodes. MALEK et coll. (1958, 1959,) studied in animals the physiologic aspects of direct and indirect lymphography as well as inflammatory changes of lymph nodes. BRUUN & ENGESET (1956), PROKOPEC & KOLINOVA (1958) and ZHEUTLIN & SHANBROM (1958) injected oily contrast medium percutaneously into lymph node tumors. SHEEHAN et coll. (1961) and WALLACE et coll. (1961) performed direct lymphography with an oily contrast medium in human subjects and obtained a filling of the aortic lymph nodes and even the thoracic duct. COLLETTE (1958) and FUCHS et coll. (1960) demonstrated by lymphography tumor involvement of the lymph nodes in the pelvic region as a cause of chronic secondary lymphedema.

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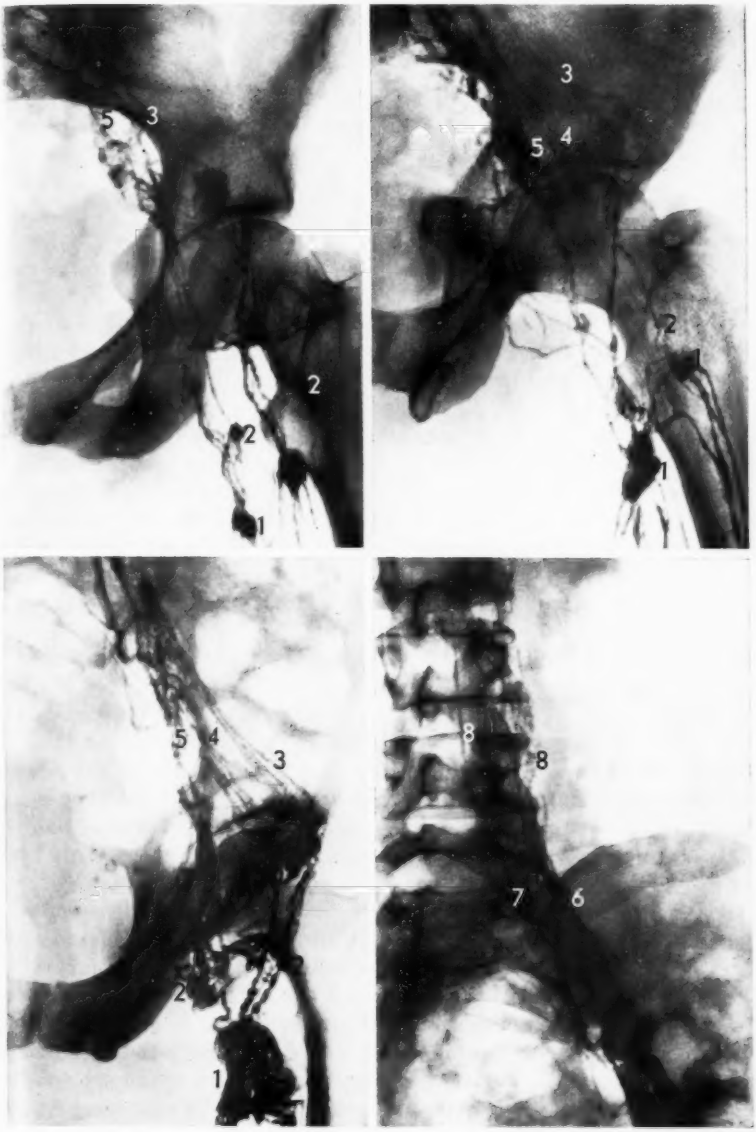

Fig. 1. Normal inguinal and pelvic lymphograms. Inferior superficial inguinal lymph nodes (1), deep inguinal lymph nodes (2), superficial lateral external iliac lymphatic group (3), deep lateral external iliac lymphatic group (4), medial external iliac lymphatic group (5), lateral common iliac lymphatic group (6), medial common iliac lymphatic group (7), aortic lymphatic group (8).

In order to evaluate critically some of the findings reported by these authors as well as to judge the practical value of lymphography in tumor diagnosis, we began to investigate a series of patients with probable malignancy of the inguinal and especially the pelvic lymph nodes. We present a preliminary report of our studies based upon the results of 94 lymphographies performed in 65 patients.

Technique

Contrast filling of the inguinal lymph nodes is relatively easy by the injection of 3 to 5 ml contrast medium into a lymph vessel on the dorsum of the foot by the KINMONTH method. Because of the resistance to the lymph flow and consequently to the passage of the contrast medium in the inguinal lymph nodes demonstration of the lymphatic system in the pelvic region is far more difficult to achieve. Following a suggestion by COLLETTE (1960) we use an automatic injection apparatus and inject 15 to 30 ml contrast medium. Starting at a low speed so as to distend the lymph vessel, the injection rate is gradually increased so that all the contrast medium is injected in about 10 minutes. The automatic injection apparatus recently described by CLEMENTZ & OLIN (1961) assures a constant rate of flow and one which may easily be controlled. To prevent retroextravasation of contrast medium at the site where the puncture needle penetrates the wall of the lymph vessel a silk ligature is placed around the needle. While injecting the contrast medium a series of 6 to 8 roentgenograms of the inguinal and pelvic region is taken at intervals of about 30 seconds. The exposures are made as soon as a burning sensation up through the leg to the inguinal region, produced by the injected contrast medium, is felt by the patient. Roentgenograms taken later than 10 minutes after the beginning of the injection of the water-soluble medium show blurred lymphatic structures due to extravasation. The exposures are made with the patient with the side to be investigated rotated slightly externally and, for the last roentgenogram, markedly rotated. We normally obtain contrast filling of the lymphatic system up to the level of the upper part of the sacrum and in some cases as high as the lumbar region.

No evidence of lymphedema due to the investigation was observed in our material and no complications, other than an infection at the incision site in one case, were recorded. The contrast media used for our series of investigation were all water-soluble, namely Urografin 60 % and 76 % and Biligrafin-forte. The two latter demonstrate the lymphatic vessels and lymph nodes with a higher contrast density, but no difference in their tendency to diffuse through the walls of the lymphatic was evident; the quality of the roentgenograms was essentially the same with both types of contrast media. The burning sensation experienced by the patients varied widely but was most marked with Urografin 76 %. The use of oily contrast media for intralymphatic injection seems not to be without risk. Necrosis and lipogranulomatous reactions in the lymph

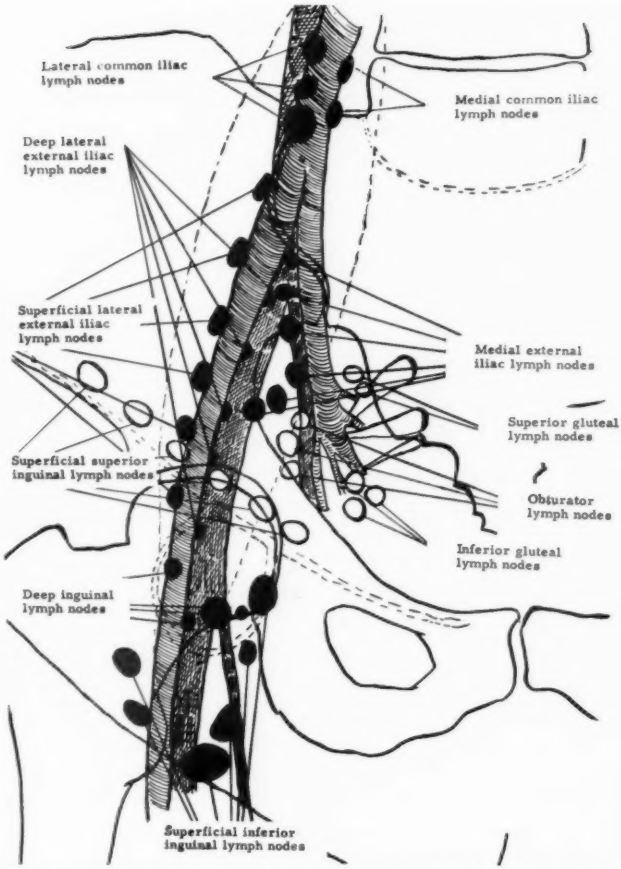
Lateral common iliac lymph nodes
Medial common iliac lymph nodes
Deep lateral external iliac lymph nodes
Superficial lateral external iliac lymph nodes
Medial external iliac lymph nodes
Superior gluteal lymph nodes
Superficial superior inguinal lymph nodes
Obturator lymph nodes
Inferior gluteal lymph nodes
Deep inguinal lymph nodes
Superficial inferior inguinal lymph nodes

Fig. 2. Schematic drawing of the inguinal and pelvic lymph nodes. *Black:* Lymph nodes demonstrated by lymphography. *White:* Lymph nodes not shown by lymphography.

nodes investigated due to damage by the contrast medium have been described (BENNETT & SHIVAS 1954; ENGESET 1958; FISCHER & ZIMMERMANN 1959; WALLACE et coll. 1961). The risk of fat embolism in the lungs has to be considered (ENGESET 1958, WALLACE et coll. 1961). MALEK et coll. (1959) demonstrated in animal experiments that water-soluble contrast media that have a tendency to remain in the lymphatic system for a relatively long period of time show a tendency to damage the lymph nodes proportional to their duration of stay in the lymphatic system. These authors state that water-

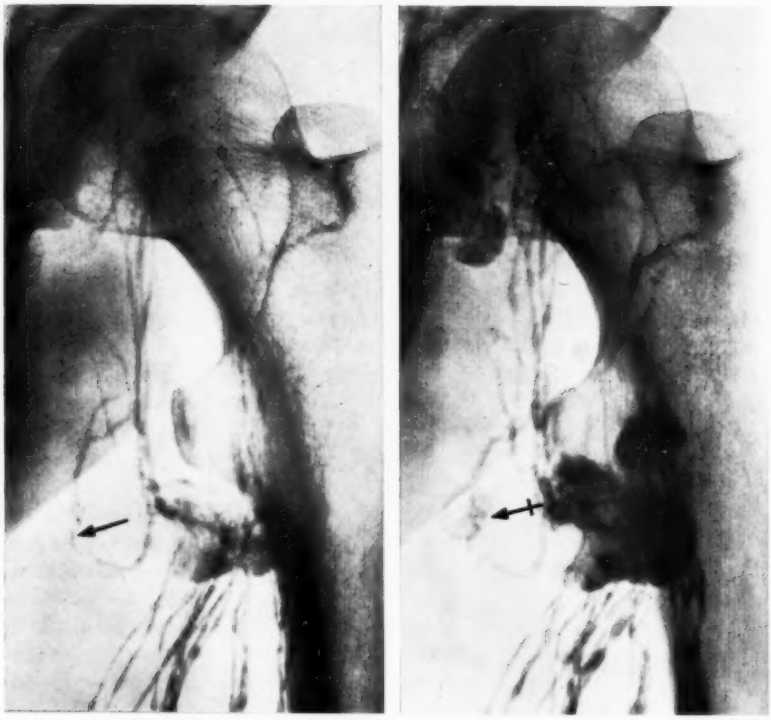

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Fig. 3. Normal lymph nodes in different stages of contrast filling. a) Early stage of filling. Only the afferent vessels of a superficial inguinal lymph node are filled (→). b) Late stage of filling. The lymph node is now entirely filled with medium (↔). A large number of superficial and deep inguinal lymph nodes are present.

soluble contrast media may stay in the lymphatic system for up to one hour and described necrotic and fibrotic changes followed by blockage of the lymphatic system and subsequent lymphedema. Since oily contrast media remain in the lymph nodes for a period of several months, further animal experiments must be carried out to determine whether they may be considered as being innocuous to the lymphatic system.

Roentgen anatomy

The nomenclature and roentgen-anatomy of the lymph vessels and lymph nodes in our series of investigations is based mainly upon the classic anatomic studies of BARTHELS (1909) and JOSSIFOW (1930) as well as upon the careful in-

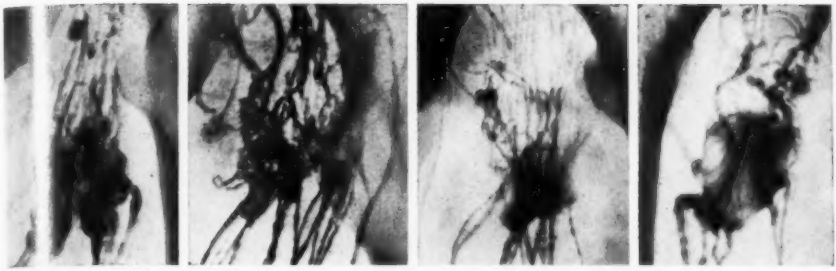

Fig. 4. Different types of normal superficial inguinal lymph nodes.

vestigations of REIFFENSTUHL (1957). The roentgen-anatomic descriptions by COLLETTE (1958), KAINDL et coll. (1958, 1960), GERGELY (1958), JACOBSSON & JOHANSSON (1959), MALEK et coll. (1959), FUCHS et coll. (1959), DEL BUONO et coll. (1959) and WELIN & JOHANSSON (in print) have also been considered.

The injection of contrast medium into the medial, and in some cases, the lateral group of subcutaneous lymphatics on the dorsum of the foot, regularly produces a characteristic appearance of the lymph vessels and lymph nodes in the inguinal and pelvic regions (Fig. 1). The medial and lateral group of subcutaneous lymphatics of the leg drain mainly into the same group of one to four inferior superficial inguinal lymph nodes. A few lymphatics may run directly to the deep inguinal or even to the pelvic lymph nodes. The numerous afferent vessels of the inferior superficial inguinal lymph nodes are normally fine and divide into several branches before entering the sinus of the lymph nodes; their efferent lymphatics fill, as an inconstant finding, some tiny deep inguinal lymph nodes. These efferent vessels are coarse and often have numerous valves and they follow the external iliac artery in two main groups of lymphatics, namely the lateral external iliac and the medial external iliac groups. The former is situated laterally to the external iliac artery and comprises a group of two to six lateral external iliac lymph nodes of various sizes. This group of lymphatics is divided into a superficial and a deep section. The former is situated ventrally and the latter dorsally to the external iliac artery. Because of the great anatomic variation both or only one of these may be present and thus filled with contrast medium. When only one section is present it is difficult to judge whether it is the superficial or the deep. The efferent lymphatics of the lateral external iliac lymph nodes are called lateral common iliac and include some small lymph nodes of the same name. Some of these efferent lymphatics form a constant connection to the medial external iliac group of lymphatics and lie dorso-medially to the external iliac artery; they include several medial external iliac lymph nodes mainly of small calibre connected by a network of wavy anastomosing lymphatics. In the sacro-iliac

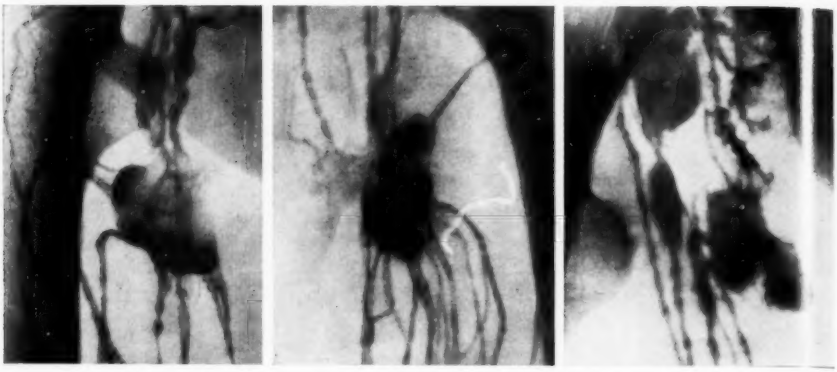

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Fig. 5. a) Normal superficial inguinal lymph node with fibrosis and fatty involution of its centre. b) Conglomeration of several small superficial inguinal lymph nodes (verified histologically). c) Lymphosarcoma (generalized in a 63-year-old man). Enlarged superficial inguinal lymph nodes with rounded filling defects and slightly irregular contours (verified at autopsy).

region this group is called, because of its relationship to the common iliac artery, the medial common iliac group of lymphatics. The lateral and medial groups of iliac lymphatics are to a great extent superimposed in roentgenograms obtained in a true frontal projection. The two groups may be seen more distinctly when the patient is turned towards the side being investigated; pelvic and inguinal lymphograms should therefore be obtained as a routine procedure in this position.

We obtained filling of the aortic lymph vessels and lymph nodes in some cases; however, a description of the lymphatic system of this region would be incomplete and premature at the present time.

Injection of contrast medium into the dorsal group of lymphatics does not give the same satisfactory results; the small number of lymphatics filled drain into a single deep inguinal or pelvic lymph node.

An exact knowledge of the topography of the lymph nodes accessible to the present technique of lymphography and of the regional lymph nodes, where metastases from a cancerous pelvic organ may be expected, is of utmost importance (Fig. 2).

We have studied the relationship between the different groups of lymphatics and the various pelvic arteries by carrying out simultaneous pelvic lymphography and arteriography as well as by localizing the various groups of lymph nodes by extraperitoneal lymph node excision (GORTON 1953, 1957).

The more medially located pelvic lymph nodes as well as the numerous superior inguinal lymph nodes cannot be demonstrated roentgenographically by the present technique. The presence of a large number of lymphatics con-

Fig. 6. Squamous cell carcinoma in a 76-year-old man with local recurrences in the inguinal region after surgical excision of the malignant inguinal and pelvic lymph nodes. Primary tumor unknown.

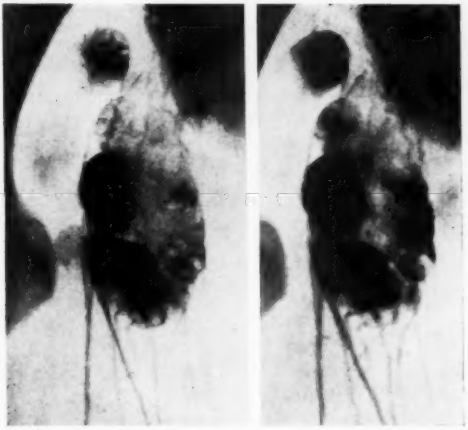

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Fig. 7. Chronic lymphadenitis in a 15-year-old boy with secondary lymphedema of right leg. Enlarged superficial inguinal lymph nodes with numerous rounded filling defects in early stage of filling (a) due to enlarged lymph follicles. Blurred structural pattern of the lymph node in late stage of filling (b) due to diffusion of the contrast medium.

necting the different inguinal and pelvic lymph nodes increases, however, the possibility of detecting early malignancy by lymphography. The centrifugal direction of the lymph flow from the various pelvic organs, ensured by the numerous valves in the lymph vessels, makes it impossible to produce a retrograde circulation so as to obtain contrast filling of the more medially located lymph nodes. Although the basic pattern of lymph vessels and lymph nodes filled in the inguinal and pelvic regions is constant, a great number of individual variations are encountered; this must be taken into account when considering the differential diagnostics.

Considerable variation in the normal structural pattern of superficial inguinal lymph nodes may be observed. Diffusion of the water-soluble contrast medium in the course of the investigation obscures small filling defects produced by lymph follicles, small inflammatory lesions and tumor infiltration (TJERNBERG 1956, COLLETTE 1958, FISCHER & ZIMMERMANN 1959, MALEK et coll. 1959). The contrast medium often passes in the first stage of the investigation directly from the afferent to the efferent lymph vessels of a lymph node without the parenchyma of the lymph node as a whole being demonstrated. It is only the continuous flow of contrast medium which provides a complete filling of these lymph nodes in the later stages of the investigation; the structural pattern of the nodes therefore to some degree changes. Lymphograms can thus only be

Fig. 8. Reticulosarcoma (generalized in a 41-year-old man). Large inguinal and pelvic tumor masses (→).

judged with accuracy in serial films which demonstrate the different stages of contrast filling (Fig. 3). Roentgenograms taken at the end of the contrast injection show only blurred and indiscernible lymphatic structures which makes an appropriate diagnosis practically impossible (Figs 3 and 7).

A wide range of variation of the structural pattern was present in a large series of patients with no clinical signs of pathologic changes in the inguinal lymph nodes (Fig. 4). The histologic studies of some of these lymph nodes led us to assume that all these structural variations represented normal a nor-

Fig. 9. Lymph node metastasis in a 33-year-old woman with carcinoma of the cervix uteri, stage III, infiltrating the vagina and urethra but not the parametrium. Enlarged lateral external iliac lymph node with numerous small rounded filling defects but regular contours (→). (Verified at operation.)

Fig. 10. Total blockage in a 43-year-old woman with carcinoma of cervix uteri, stage II, infiltrating upper part of vagina but not the parametrium. Total obstruction of medial external iliac lymphatic group (→) due to metastases in medial external iliac lymph nodes. Collateral circulation through lateral external iliac lymphatic group (↔). (Verified at operation.)

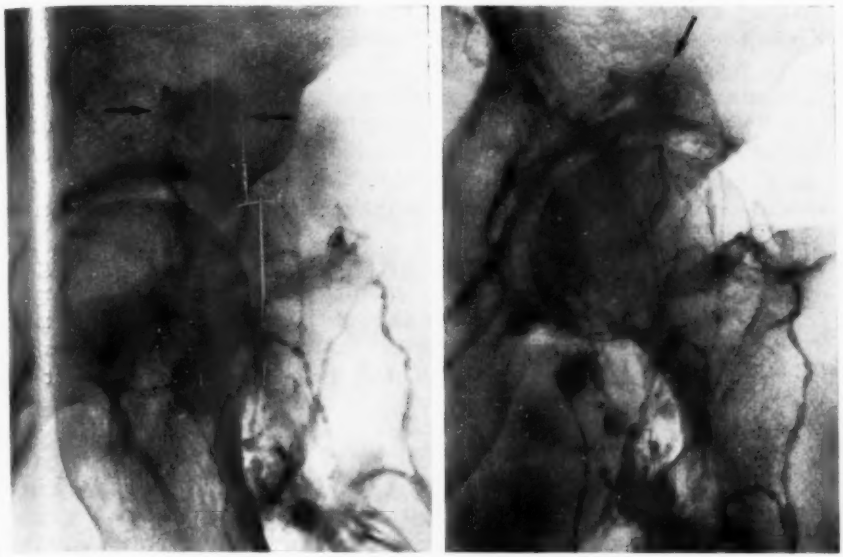
malities. The replacement of the central part of the lymphoid tissue by fatty and connective tissue in inguinal lymph nodes of elderly patients, a fact recognized by pathologists, is clearly demonstrated by lymphography (Fig. 5a). A conglomeration of several small lymph nodes may sometimes hardly be differentiated from a single large inguinal lymph node (Fig. 5b).

Fig. 11. Total blockage due to tumor infiltration in a 42-year-old woman with carcinoma of the cervix uteri, stage III, infiltrating the parametrium. Non-functioning left kidney at urography. Total obstruction of distal part of medial external iliac lymphatic group (→). Collateral circulation through the lateral external iliac group of lymphatics (↔). Lymph node metastasis in a lateral external iliac lymph node.

Diagnosis of pathologic changes

Accurate diagnosis of primary tumors and early metastases in pelvic and inguinal lymph nodes is one of the most important goals of pelvic and inguinal lymphography. Differentiation between normal and pathologic findings especially in these early states of tumor involvement, is often most difficult.

Normal inguinal lymph nodes (Figs 3, 4 and 5 a—b) and inguinal lymph nodes of patients with lymphosarcoma (Fig. 5c), lymphogranuloma, squamous cell carcinoma (Fig. 6), and chronic non-specific inflammation (Fig. 7) may resemble each other to a very high degree. With due regard to this fact we are inclined to believe that a definite diagnosis of the different forms of lymph node tumors is hardly possible by means of lymphography. Further investigations are being carried out with a view to obtaining more information on the



a b

Fig. 12. Lymph node metastasis in a 44-year-old woman with carcinoma of the cervix uteri, stage III, infiltrating the parametrium. Enlarged lateral external iliac lymph node with irregular contours and filling defects in peripheral parts of lymph node due to tumor infiltration (→). (Verified at operation.)

different types of normal and pathologic structural patterns of inguinal and pelvic lymph nodes.

The presence of malignant primary tumors of the lymphatic system may, however, be diagnosed with some certainty when the lymph nodes are considerably enlarged and present a structural pattern far removed from the normal. Lymphography in such cases affords valuable information about the site and extent of the massive lymphomas, which is often not possible by other means of investigation (Fig. 8). In cases in which the nature of an expansive process cannot be diagnosed clinically, its contrast filling will demonstrate its association with the lymphatic system.

Early metastatic involvement of regional lymph nodes may be shown by means of lymphography when clinical signs of metastatic spread are absent or only probable.

In a patient with carcinoma of the cervix uteri, stage III, infiltrating the vagina and urethra but not the parametrium, lymphography showed an enlarged lateral external iliac lymph node with numerous small rounded filling

defects but regular contours (Fig. 9). The diagnosis of metastatic involvement was made and subsequent operation showed a metastatic lymph node tumor attached to the psoas muscle.

Another patient with carcinoma of the cervix uteri, stage II, infiltrating the upper part of the vagina, presented on lymphography total blockage of the medial external iliac group of lymphatics with collateral circulation over the lateral external iliac group of lymphatics. Extraperitoneal lymph node excision revealed metastatic involvement of the medial external iliac lymph nodes (Fig. 10).

Similar findings of obstruction may also be present in cases of direct malignant infiltration of the parametrium (Fig. 11). Enlarged lymph nodes with irregular contours produced by filling defects in the peripheral parts of the lymph nodes due to tumor infiltrations may be mistaken for metastases. These changes may be evaluated more accurately by obtaining roentgenograms in different projections (Fig. 12).

Normal lymphographic findings do not exclude tumor involvement of lymph nodes in the pelvic region not accessible by the present technique of investigation. In a case of carcinoma of the cervix uteri, stage I, no pathologic changes in the lymphatic system filled at lymphography could be detected but metastases in the obturator lymph nodes, which are not filled with contrast medium by the present lymphographic technique, were found later at extraperitoneal lymph node excision.

Conclusions

Contrast filling of inguinal and pelvic lymph nodes may be achieved best by automatic injection of large quantities of a water-soluble contrast medium. Serial roentgenograms in different projections give the most dependable diagnostic results. Knowledge of the topography and the roentgen-anatomy of the inguinal and pelvic lymph nodes, as well as the lymphatic drainage of the various pelvic organs, are of utmost importance for accurate diagnosis.

Normal inguinal lymph nodes present a great variation of structural patterns. It is often difficult to distinguish these from pathologic changes.

Primary tumors and metastases in pelvic and inguinal lymph nodes, which cannot be approached clinically, may be demonstrated by means of lymphography.

A certain number of inguinal and pelvic lymph nodes cannot be filled with contrast medium by the present technique of lymphography. Normal lymphographic findings do thus not exclude malignancy of inguinal and pelvic lymph nodes.

SUMMARY

T[he] different patterns of the normal roentgen anatomy of the inguinal and pelvic lymphatic syste[m] demonstrated by automatic injection of a water-soluble contrast medium are described. The [di]agnostic problems of inguinal and pelvic lymphography are discussed particularly in resp[ect] to the value of the method for an early detection of primary tumors and metastases.

ZUSAMMENFASSUNG

D[ie] verschiedenen Aspekte der normalen Röntgenanatomie der Leisten- und Beckenlymphknot[en] werden demonstriert. Ihre radiologische Darstellung gelingt durch automatische Injekti[on] von wasserlöslichem Kontrastmittel. Mehrere diagnostische Probleme der inguinalen und [pe]lvinen Lymphographie werden diskutiert, besonders im Hinblick auf den Wert der Meth[o]de für eine Frühdiagnose von Primärtumoren und Tumormetastasen.

RÉSUMÉ

Les aspects normaux de la chaine ganglionnaire inguino-ilio-pelvienne sont présentés. Leur mise en évidence est effectuée par injection d'un produit de contraste hydrosoluble au moyen d'une seringue automatique. Plusieurs problèmes diagnostiques de la lymphographie inguinale et pelvienne sont discutés. L'accent est spécialement mis sur la valeur de cette méthode pour le diagnostic précoce des métastases ganglionnaires des tumeurs pelviennes et des lymphomes malins.

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FRO THE RADIOLOGICAL INSTITUTE (DIRECTOR: PROF. G. G. PALMIERI) OF BOLOGNA UNIVERSITY, ITALY.

ANGIOCARDIOGRAPHIC DEMONSTRATION OF THE VALVES OF THE AZYGOS VEIN IN TRICUSPID STENOSIS

by

G. Tori and G. F. Garusi

The valves of the azygos vein are situated in the middle or posterior third of its arch and are usually two in number. Three valves, or only one valve, may occasionally be present; when single the valve is always rudimentary (Sylwanowicz).

We have been able to demonstrate the anatomical details of the valves during angiocardiography in cases of reflux of contrast medium into the azygos vein, or after the intraosseous injection of contrast medium. The cusps of the valve, which are mostly double and face forwards, become visible as contrast medium fills the valvular pockets. Being at the level of the so-called intermediate part of the azygos arch, the valves are projected axially by the roentgen beam, producing a 'coffee-bean' appearance. The halves of the 'bean', which are almost rounded in shape, correspond to the two contrast-filled pockets, and the central separating line represents the slit between the two cusps (Fig. 1a). The edges of the valves vary in position and size (Fig. 1b). They are best seen at reflux in the antero-posterior projection but may also be visible in the lateral projection, sometimes only as bulges in the vein. In frontal roentgenograms the valves are generally superimposed upon the superior vena cava (Fig. 2a) but may also be projected outside it as dependent on the shape and position of the intermediate part of the arch of the azygos vein (Fig. 2b). If the valves lie in the posterior third of the arch, which pursues a medio-lateral course, the valves will be seen from the side instead of from an axial direction, or more or less obliquely, producing what we have termed 'snake-jaws' appearances (Fig. 3).

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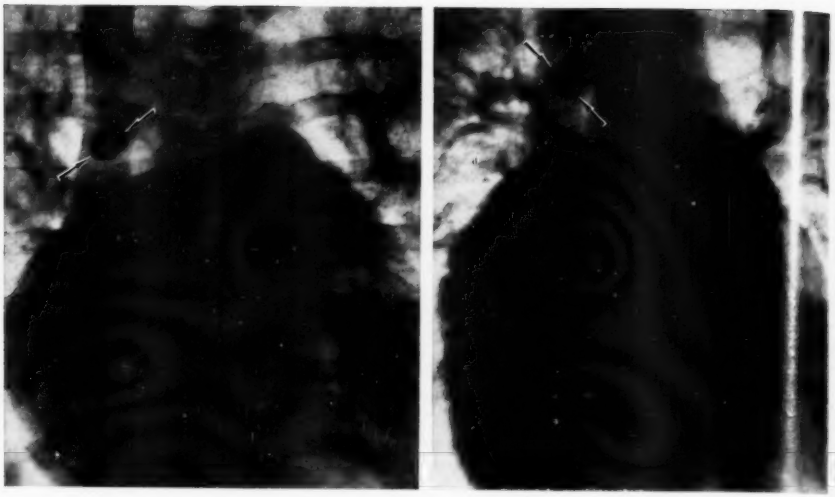


a b

Fig. 1. Valves of the arch of the azygos vein during angiocardiography in two cases of tricuspid stenosis. a) 'Coffee-bean' image with equal borders. b) The borders are unequal in size and differently placed. In both cases the contrast medium is retained in the post-valvular pockets.

a b

Fig. 2. Valves of the arch of the azygos vein and their relation to the superior vena cava in two cases of tricuspid stenosis. The image of the post-valvular pockets is projected within the superior vena cava (a) and outside it (b).

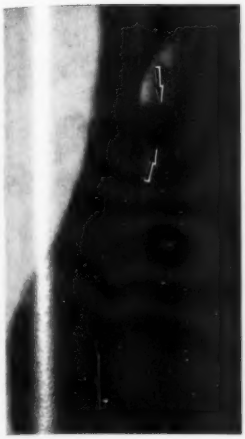


Fig. 3. 'Snake-jaws' image of the valvular apparatus of the arch of the azygos vein in a case of tricuspid stenosis associated with mitral disease.

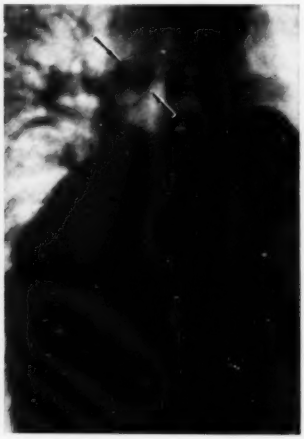
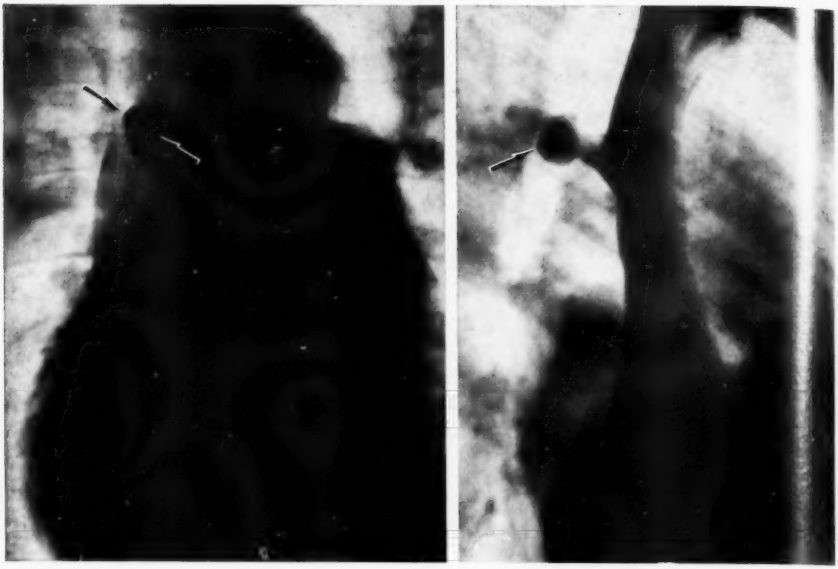


Fig. 4. The valves of the arch of the azygos vein in two orthogonal simultaneous projections in a case of tricuspid stenosis. The cusps, which have a pointed contour in a lateral projection, suggest competence.

The images described are produced by more or less competent valves, as may be seen more clearly in the lateral views of Figs 4 and 5, in which the edges of the valves appear pointed or rounded in shape. We have encountered such valve images particularly in cases of retarded emptying of the right atrium due to tricuspid stenosis although we have not been able to demonstrate them in all such cases. These features have been observed after injection of the contrast medium through a catheter with the tip placed in the right atrium (Fig. 6) as well as after injection into the brachial vein. The valves have not been visible in cases of moderate reflux of contrast medium from the superior vena cava into the azygos vein, or in cases in which the reflux has been so marked that the whole arch and a small part of the ascending tract of the azygos vein have been filled. The 'coffee-bean' appearances persist for some 10 to 15 seconds after the injection.

We have observed reflux into the azygos vein from the vena cava in numerous cases of mitral valve disease, with moderate stasis and no involvement of the tricuspid valves, but the valves have never been visible in such cases. They have very rarely been observed in congenital defects with hypertension of the right cavities of the heart (tetralogy of Fallot) (Fig. 5).



a b

Fig. 5. Example of competence of the valvular cusps of the azygos vein in a case of tetralogy of Fallot. The cusps appear rounded in the lateral projection (b).

It is not easy to explain how this filling of the valvular pockets is produced. It is above all necessary for the reflux to reach the valvular system and for the valvular pockets to be enlarged, but we have not been able to find any relationship between the degree of enlargement of the superior vena cava and the post-valvular segment of the azygos vein and the morphology of the valvular system. During the initial phase of inspiration, the pressure within the superior vena cava is negative and then gradually becomes positive; this might produce a persistent reflux from the vena cava into the azygos vein, for which the determining factor on the other hand must be the existence of a considerable rise in pressure in the right atrium. In addition to the reflux into the azygos vein, there was in almost all of our cases of tricuspid stenosis a more or less marked reflux of contrast medium into the first part of the inferior vena cava and some of the hepatic veins.

Conclusions

The valvular system of the azygos vein, situated in the middle or posterior third of the azygos arch, taken in axial direction by the roentgen beam in a. p. projection, produces characteristic images. Its filling is often of long duration. It appears from a study of our angiocardiographic material of congenital

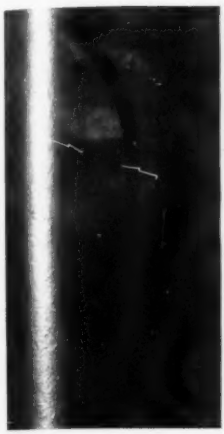


Fig. 6. Severe tricuspid stenosis studied with selective angiocardiography. Typical 'coffee-bean' image of the azygos valves, obtained obviously through reflux.

a

b

Fig. 7. The valvular image of the azygos vein in cases without right endo-atrial stasis. a) Coarctation of the aorta with lateral displacement of the superior vena cava due to a dilated ascending aorta. b) Mediastino-pulmonary tumour with displacement and probably infiltration of the superior vena cava.

defects with hypertension of the right heart, and of mitral and tricuspid defects alone or in combination with other diseases, that the radiologic visibility of the valvular system of the azygos vein in the a. p. projection constitutes an important sign of prolonged stasis in the right heart due mainly to tricuspid stenosis. The sign is however not pathognomonic as we have observed three cases without high pressure in the right atrium. One of these was a case with coarctation of the aorta and the other two were cases of mediastino-pulmonary tumours (Fig. 7).

The value of the finding described, which is frequent in tricuspid stenosis (14 out of our 20 cases), is in our opinion not invalidated by the existence of the aforementioned three cases (out of a material of 250 angiocardiographies). It is possible that in these three cases without increased pressure in the right atrium lateral displacement or compression of the superior vena cava may have caused the valve images to appear.

SUMMARY

The angiocardiographic appearances of the valvular system of the arch of the azygos vein are described. The visibility of the valves is particularly frequent in cases of tricuspid stenosis.

ZUSAMMENFASSUNG

Das angiokardiographische Aussehen des Klappensystemes des Bogens der Vena azygos ird beschrieben. Die Sichtbarkeit der Klappen ist in Fällen mit Trikuspidalklappenstenos e- sonders häufig.

RÉSUMÉ

Les auteurs décrivent l'image angiocardiographique du système valvulaire de la cros de l'azygos. La visibilité des valvules est particulièrement fréquente en cas de sténose tricuspidi ne.

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INJURIES OF THE CARPAL SCAPHOID IN CHILDREN

by

HERBERT MÜSSBICHLER

It has previously been considered that fractures of the carpal scaphoid are rare in children (RETTIG, BLOUNT, EHALT). It would appear to us, however, that such fractures are not uncommon, and that our roentgendiagnostic experiences of scaphoid injuries in children under 15 years of age may be of interest. The patients were examined and treated in our clinic during the years 1952 to 1960.

Material and Methods. In addition to the usual views (Figs 1 and 2), frontal, lateral, and lateral oblique (a position midway between pronation and supination with the hand slightly flexed dorsally and deviated toward the ulna), we have also used a projection with the hand in more or less extreme pronation (Fig. 3) giving tangential views of the dorsoradial surface of the scaphoid bone (Figs 1, 2, 5, 6, 7). Films without intensifying screens were used.

Among 3 406 children under 15 years of age referred for roentgen examination of the hand or wrist there were 107 with roentgenologic evidence of damage of the carpal bones; 100 of these had a fracture through the scaphoid bone and these cases were used as the material for the present study. The distribution of different types of fracture in adults and children, as ascertained from the literature as well as from our own series, is presented in the Table on p. 362 while the Diagram, p. 363, shows the distribution over different age groups.

Submitted for publication 27 April 1961.

Table

Frequency and location of carpal scaphoid fractures in children and adults

	Authors	Number of fractures	Proximal	Waist	Distal	Avulsions at radial-dorsal aspect
In adults	Andersen and Therkelsen	135	25	55	55	
	Ruzicka and Heublein	16	6	8	2	
	Trojan	873	141	513	219	
In children	Müssbichler	100	—	15	33	52

Results

In our material, fractures were observed on the medial and distal but not on the proximal part of the scaphoid. Forty-eight cases had fractures and fissures of the type commonly seen in adults; in the remaining 52 cases the fractures were of a different appearance, the characteristic feature being that one or more fragments had become detached from the dorsoradial surface of the scaphoid distal to its centre (Figs 2, 5, 6, 7). In 6 of these cases, transverse fractures of the distal part were also observed. The fragments were best seen in the ordinary frontal projection or in films taken with the hand in pronation. Only in a few cases were they visible in the lateral oblique position, and in none in the lateral projection. As films in the pronation position were not consistently obtained in the present series the incidence of avulsion of small fragments was probably greater than has been indicated.

Control examinations. In 30 children with avulsions who were treated with a plaster cast or a plaster splint for 2 to 3 weeks and followed up, the healing time was 3 to 6 weeks; in the group with fractures and fissures through the medial and distal parts of the scaphoid healing took place within 4 to 7 weeks. Pseudo-arthrosis was observed in two neglected cases. As in the case of adults, increased density in the fracture area, indicating endosteal callus formation, was observed during the healing of the transverse fractures (Lindgren).

In all the fracture cases, there was a local clearly delimited area of increased density in the soft tissues near the dorsoradial aspect of the scaphoid bone (Figs 1, 2, 5, 6, 7). The anatomical background underlying this change was studied both by making comparisons with arthrograms of the wrist from adults and by roentgen examination of specimens. Judging by ten arthrographic examinations, the joint capsule on the dorsoradial aspect of the scaphoid bone formed a recess corresponding in position to the anatomic snuff box ('tabatière anatomique', Fig. 3). After injection of 3 ml of water (Fig. 4 b) and 2 ml of Urografin 30 % (Fig. 4 c), the recess could be well demonstrated.

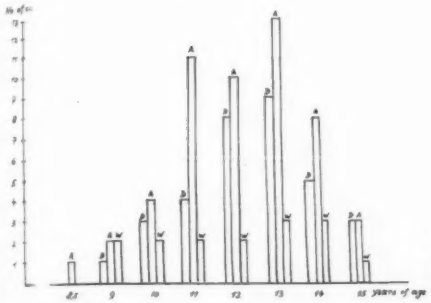
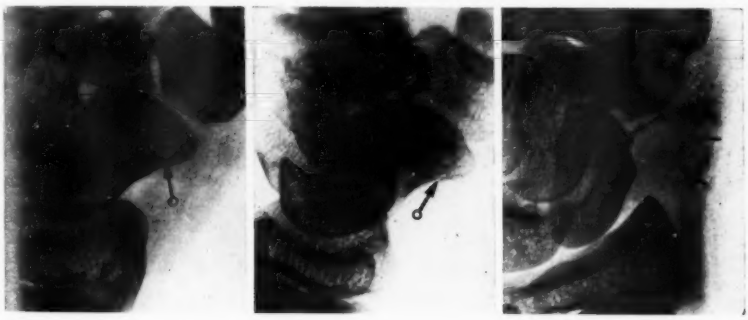


Diagram showing the number, types and location of fractures of the scaphoid in relation to the age of the patients. A — avulsions, D — distal parts, W — waist of scaphoid.

The position and shape of this recess corresponded to the area of increased density in the soft tissues which was consistently found in our material of scaphoid fractures and which thus appeared to be due to exudation into the joint-capsule recess near the scaphoid bone. The occurrence of exudation in this recess was also studied in conventional views of the wrist and carpal bones in cases with other lesions in and around the wrist joint. Exudation was observed in all 7 cases with fractures in other carpal bones, as well as in a few cases with contusion of the back of the hand. At the same time, only one exudation was encountered in 10 cases with epiphysiolysis of the radius, and there was no exudation among 20 radius fractures, some of which were combined with detachment of the styloid process of the ulna. In these cases swelling of the 'external' soft tissue, not to be confused with an exudation into the joint capsule, was sometimes present (Fig. 8).



a b c

Fig. 1. Lateral oblique, lateral, and pronation views showing the line of fracture from the volar (tubercle ○→) to the dorsoradial aspect (|→). Expansive swelling of the joint-capsule recess (→).

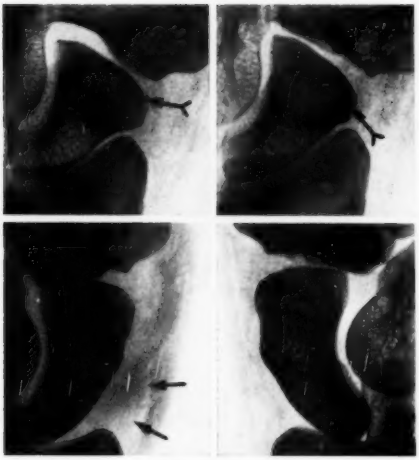


Fig. 2

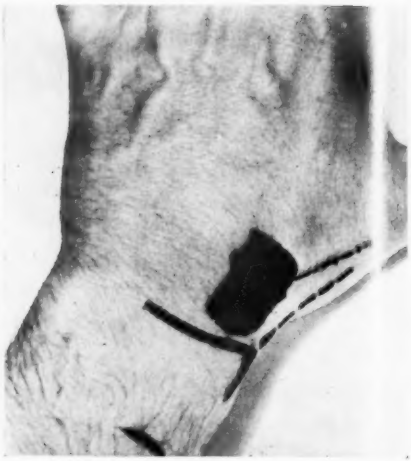


Fig. 3

Fig. 2. Avulsion of small fragment from distal surface of scaphoid bone in a 14-year-old boy. The fragment (←) is only visible in the true frontal projection with slight pronation (the upper views). The effusion in the joint-capsule recess is best seen in extreme pronation (← in lower left view). The healthy side is shown for comparison (lower right).

Fig. 3. Photograph of the pronated hand for demonstration of the relationship of the dorsoradial aspect of the scaphoid bone and the anatomic snuffbox, which is bordered by the tendon of M. extensor pollicis longus (——·——) and brevis (— — — —).

A shell-shaped ossification centre at the tuberosity of the scaphoid (Fig. 7), observed in 20 cases in our series, was of interest from the differential diagnostic point of view. If its shape and position are taken into consideration there should be little risk of misinterpreting this as a fracture. Nor should any differential diagnostic difficulties arise in the interpretation of other, more uncommon, separate ossification centres such as the os centrale, epi- and hypolunatum, radiale externum, and trapezium (KÖHLER & ZIMMER, O'RAHILLY).

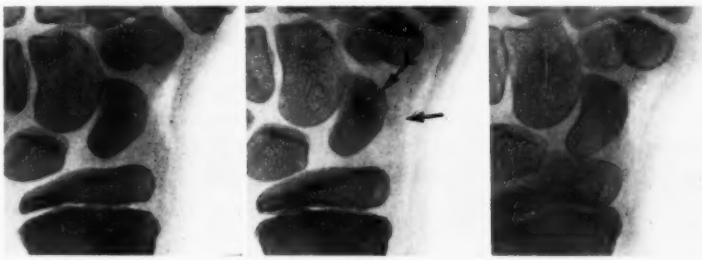
As the small avulsions of flake-like fragments from the dorsoradial aspect of the scaphoid bone lay close to the uneven zone on the scaphoid forming the insertion for the capsule in the radio-scaphoid and multianguli-scaphoid joints (see the schematic drawing to the extreme left in Fig. 9), it seems highly probable that they had arisen as a result of chipping at the capsular insertion.

Discussion

In BACORN & KURTZKE's review of 2 566 hand lesions in patients over 15 years of age the incidence of scaphoid fractures was 2.7 %. Approximately the same incidence was noted in our material consisting exclusively of children

a b c

Fig. . Films obtained in extreme pronation for demonstration of the joint-capsule recess in a 16-year-old ... y. Normal soft tissue before (a) and after (b) injection of 3 ml water into the radiocarpal joint at t... site of the ulnar styloid process, causing expansion of the capsule recess (←). c) The same joint filled with 2 ml Urografin 30 %.



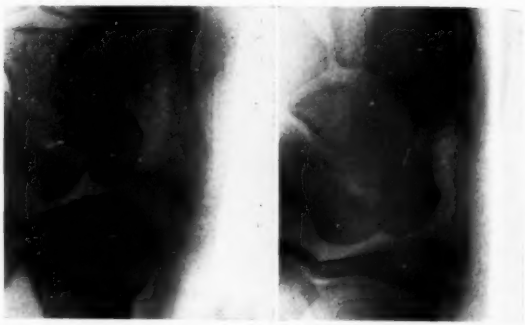
a b c

Fig. 5. A fragment avulsed at the typical site, visible in pronation only, in a 9-year-old girl. a) Healthy side. b) Recent avulsion (←) associated with effusion into the joint-capsule recess (←). c) Four weeks after the accident, the avulsion is healed and the effusion has subsided.

Fig. 6 a 6 b Fig. 7 a 7 b 7 c

Fig. 6. a) Avulsion of a small fragment (←) at the typical site, visible only in extreme pronation, associated with an effusion in the joint-capsule recess (←). b) Healthy side for comparison.

Fig. 7. a) and b) Lateral oblique projections. Supernumerary ossification centres at the tubercle (←) and radial styloid process (os radiale ext. ↔). c) Typical avulsion of a small fragment visible only in extreme pronation (←).



a b

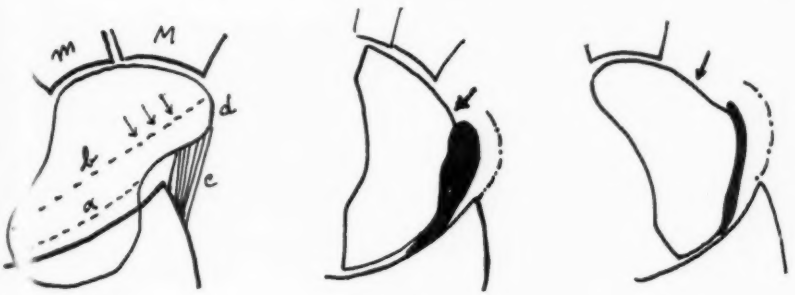
Fig. 8. a) Swelling of the 'external' soft tissue in a case of fracture of the metaphysis of the radius. No expansion of the joint-capsule recess is visible. b) Healthy side for comparison.

under 15 years of age; scaphoid lesions comprised 2.9 % of this series and were commonest between the ages of 11 and 13 years.

Injuries of the scaphoid bone have been said to be more uncommon in children than in adults. This view has probably arisen because the fractures are less marked in children and thus are easily overlooked.

Waist fractures predominate in adults; in our series these were present in only one-sixth of the cases. Fractures through the proximal part of the bone were entirely absent in our material. As fractures in the distal area usually occur in the child as fissures, the roentgen films must be of high quality. Avulsions with detachment of small fragments from the dorsoradial surface of the scaphoid constituted 52 % of our material and thus may be regarded as typical of childhood. These fragments are best seen if the wrist joint is placed in more or less extreme pronation so that the fracture surface is taken in a projection tangential to the beam (see the middle and extreme right schematic drawings in Fig. 9). This projection has occasionally been used by earlier investigators, but not with a view to studying this type of avulsion or diagnosing the joint-capsule effusion. As LINDGREN has pointed out, it is important from the technical standpoint that films without intensifying screens should be used. This technique gives good delineation of soft tissue changes as well, and consequently permits the demonstration of exudations into the joint-capsule recess of the wrist. Such exudations occur consistently in fractures of the scaphoid and other carpal bones, but are rare in other injuries of the wrist. The exudations have been described clinically as 'swelling of the anatomic snuffbox' (Fig. 3) and considered typical of fractures of the carpal scaphoid (WATSON-JONES).

In accordance with the usual practice in paediatric roentgenology we examined the healthy side as well; the films of the unaffected side were of considerable assistance in the diagnosis of effusion in the joint-capsule recess. The degree of this swelling in the scaphoid capsule recess was not dependent on the type of the fracture, and with healing of the fracture the effusion subsided (Fig. 5).



a b c

Fig. 1. a) Schematic drawing of a dissection of the dorsal aspect of the scaphoid bone placed in the lateral oblique position. The letters *a* and *b* indicate insertion of ligamentary joint capsule, facing the radius and the multanguli, respectively. On extension of the wrist the radius moves towards the line *a* where its action will be arrested by strong ligaments (*c*), connecting the radial styloid process and the tubercle of the scaphoid (*d*). The multanguli bones are arrested at line *b*, their motion being halted by the dorsal joint capsule. In extreme extension small flakes of bone may become avulsed along the line *b*. M — multangulum majus, m — multangulum minus. b) and c) Schematic drawings of roentgenograms with the hand in slight and extreme pronation respectively. The small fragments avulsed from the dorso-radial surface are now projected free from the main bone and become evident. The black areas correspond to the normal joint capsule recess which becomes expanded (— — —) when a fracture of the scaphoid has occurred. ↓ points to typical site of avulsion.

It should be stressed that the conventional frontal and lateral projections commonly used in injuries of the distal end of the forearm are equally as important for the detection of scaphoid fractures as the pronation and oblique projections (Fig. 2). The prognosis in regard to healing is good. Bony union occurred within 7 weeks in the transverse fractures and within 6 weeks in the cases with avulsion. Although the latter injuries may be described as 'trivial', they may cause persistent pain if the wrist is not immobilized for a period of at least two weeks. The primary diagnosis of these small lesions may therefore be considered valuable.

SUMMARY

One hundred cases of fracture of the carpal scaphoid bone in children have been studied. Fifty-two of these were avulsions of small fragments from the radial-dorsal aspect of the scaphoid. Exudation into the joint-capsule recess of the scaphoid was consistently observed in all fractures of the scaphoid or other carpal bones and this sign may thus be useful as a diagnostic aid in uncertain cases.

ZUSAMMENFASSUNG

Es wurden 100 Navikularefrakturen an Kindern studiert. In 52 Fällen handelte es sich um kleine Fragmentabrisse vom radialen dorsalen Teil des Kahnbeins. Bei allen Frakturen sowie auch bei den Frakturen der übrigen Handwurzelknochen konnte konstant ein Erguss im navikularen Gelenkskapselrecessus festgestellt werden. Sein Vorhandensein kann bei fraglichen Fällen von diagnostischer Bedeutung sein.

RÉSUMÉ

L'auteur a étudié cent cas de fracture du scaphoïde carpien chez l'enfant. Dans cinqu nte-deux cas il s'agissait d'arrachement de petits fragments de la face radio-dorsale du scaph ide. Dans toutes les fractures du scaphoïde ou des autres os du carpe, on a constaté, de çon constante, un épanchement dans le récessus scaphoïdien de la capsule articulaire; ce gne peut donc contribuer au diagnostic dans les cas douteux.

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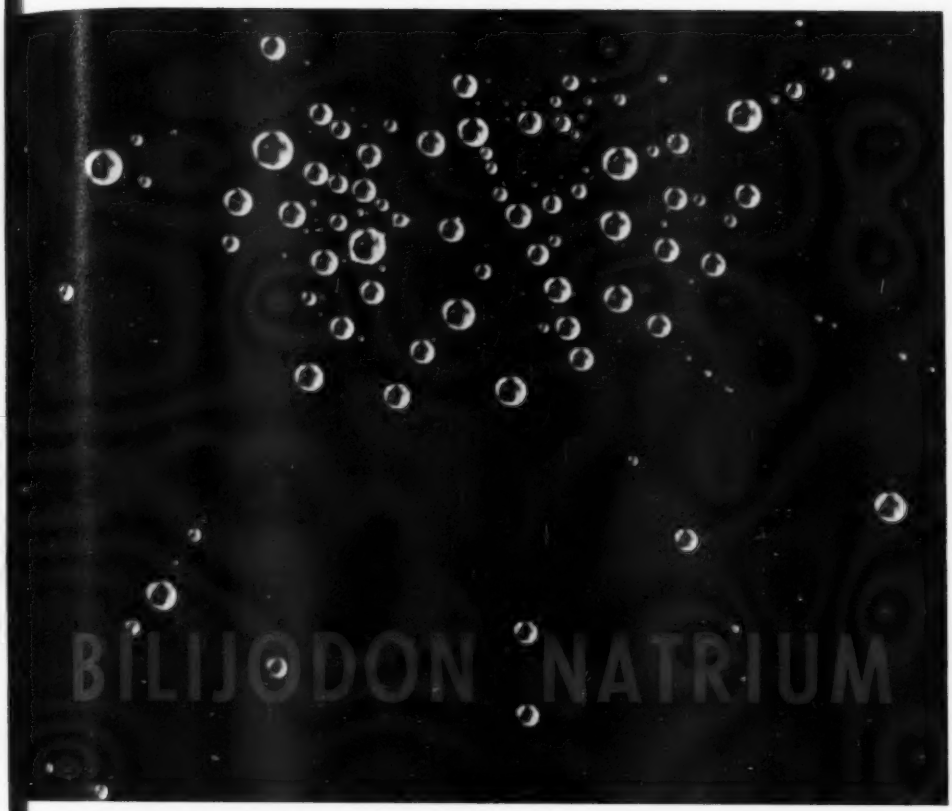

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FRO THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR: PROF. SÖLVE WELIN), MALMÖ ALLMÄNNA SJUKHUS, MALMÖ, SWEDEN.

HAEMODYNAMICS OF THE PELVIC VEINS IN INCOMPETENCE OF THE FEMORAL VEIN

by

GÖRAN NYLANDER

The strain obstruction syndrome of the femoral vein described by GULLMO (1957) has received much space in the discussion of the aetiology of varices. This phenomenon, which occurs in patients with incompetent veins of the legs, consists of complete obstruction of the femoral vein distal to the inguinal ligament on straining (Fig. 1).

In the GULLMO (1956) modification of the DOS SANTOS and LUKE method for retrograde femoral phlebography, contrast medium is injected percutaneously into the femoral vein just below the inguinal ligament while the patient is straining. If the valves in the femoral vein or the long saphenous vein are incompetent, the medium will flow in a retrograde direction down through the leg veins. If the valves are competent, however, the contrast medium will pass down only to the first valve of the respective veins, and the remainder will fill the femoral and external iliac veins proximal to the site of injection (see Fig. 2). GULLMO (1957) suggested that this phenomenon might be due to a compression of the femoral vein in the lacuna vasorum by a latent femoral hernia bulging down into the femoral canal in association with straining. Femoral herniation would according to this author compress the vein and thereby obstruct venous drainage of the leg and favour the development of varices.

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Fig. 1. Complete obstruction of the femoral vein on straining.

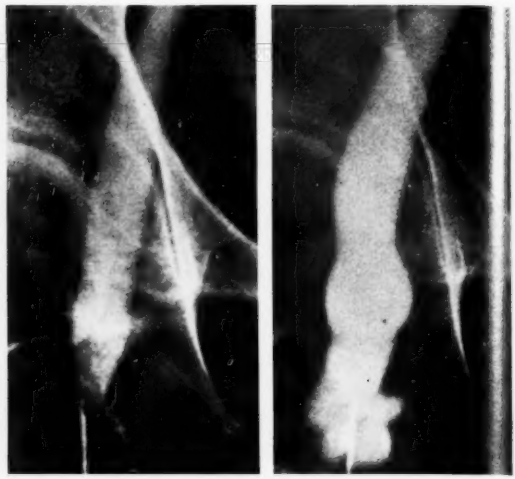
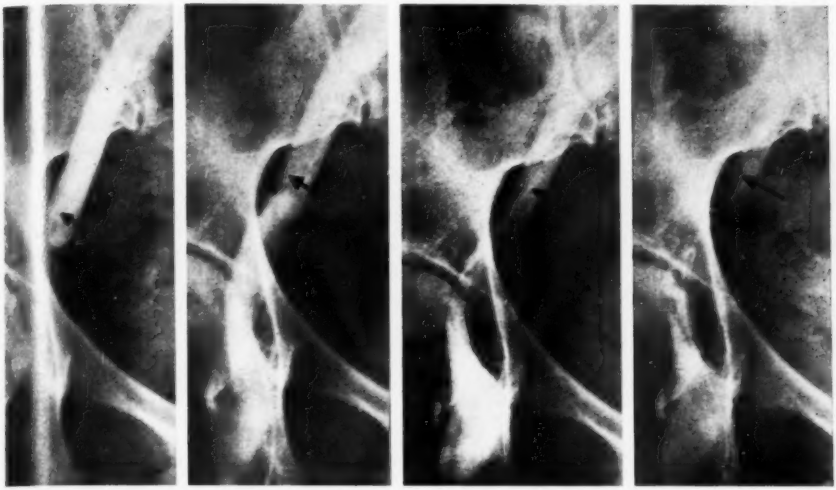


Fig. 2. Normal femoral vein without straining (left), and with straining (right).

These theories have, however, not been generally accepted, and the role played by purely mechanical factors in the aetiology of varices is not properly understood.

From a haemodynamic point of view a normal vein differs from a vein with incompetent valves in that under certain conditions the blood in the latter can be made to flow in a retrograde direction while in normal veins this is soon prevented by the venous valves. In the interpretation of the occlusion phenomenon it is necessary first to realize what happens in a normal vein in the lacuna vasorum during straining. Straining is accompanied by a marked fairly rapid increase in the intra-abdominal pressure (LIEDHOLM 1939, MENGERT & MURPHY 1934). Since the inferior vena cava and the common, external and internal iliac veins lie within the muscle walls responsible for the increase in the intra-abdominal pressure during straining, the pressure in the abdominal veins will also be increased to a corresponding degree. The intra-abdominal pressure during straining considerably exceeds the pressure in the soft tissues in the trigonum femorale and thereby also in the femoral vein; the consequent difference between the pressure in the veins above and below the inguinal ligament causes blood to flow from the external iliac vein to the femoral vein. This retrograde flow closes the uppermost valves in the femoral vein and the long saphenous vein. Because of the increased pressure the vein distal to the inguinal ligament will be distended from the ligament down to the level of the first valve and the proximal part of the femoral vein will



a b c d

Fig. 3. External iliac vein in frontal projection. a) Normal width. b) Initial phase of straining. c) Decreased diameter. d) Vein pressed against the psoas muscle.

expand to such an extent that the pressure in the vein will equal the intra-abdominal pressure. Once this stage has been reached, the retrograde flow will cease.

This theory is supported by observations made in an investigation described below.

Personal investigation

In 39 subjects without any signs of incompetence of the femoral vein, the width of the vein between the inguinal ligament and its uppermost valve was found to widen on the average from 14 to 17 mm during straining. If it be assumed that the lumen of the vein at this level is circular, this will imply an increase in the calibre of the vein from 165 to 225 mm^2, corresponding to 36 % of the transverse area of the vein. The increase in the width of the femoral vein in association with straining is illustrated in Fig. 2, which also shows that the external iliac vein is well filled both before and during straining and that the width of this vein is not substantially affected.

In patients with incompetent veins and the strain obstruction syndrome, straining has the opposite effect (Fig. 3). To demonstrate this difference a thin polythene catheter was inserted percutaneously into the femoral vein and advanced until its tip lay in the external iliac vein (cf. SELDINGER). The

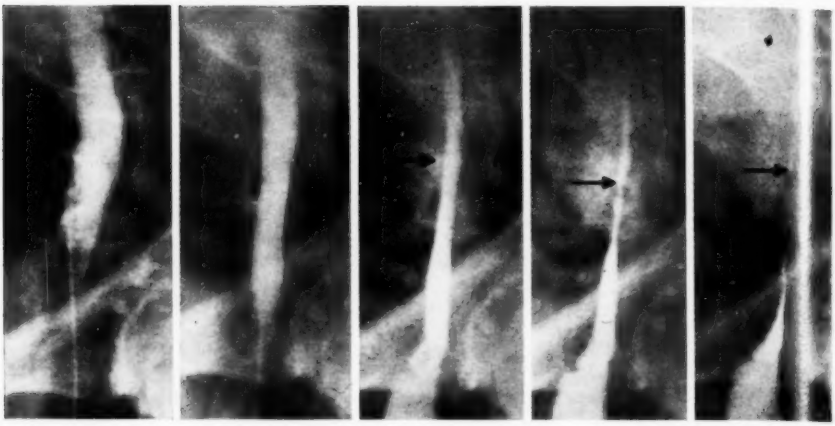


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Fig. 4. Roentgenograms with beam forming a tangent with the ileo-psoas muscle.

catheter was fine and flexible so that it could not influence the occlusion. Urografin 60 % was injected continuously throughout the investigation. The patient was instructed first to relax and then to strain as much as possible in order to secure roentgenograms of the external iliac vein and femoral vein before and during straining. Films were taken at a varying rate of 2 to 4 per second with an automatic film changer.

In Fig. 3, (a) depicts the normal width of the external iliac vein in the frontal projection with the patient relaxed, while the initial phase of straining with the contrast medium passing down through the external iliac vein towards the femoral vein is illustrated in (b). The diameter of the external iliac vein has begun to decrease in (c) and a small portion of the contrast medium injected through the catheter has passed up to the vena cava, while the bulk of the medium has been forced down in a retrograde direction into the femoral vein. In (d) it is shown how the external iliac vein is pressed against the psoas muscle and cannot be filled with medium despite continuous injections. This sequence of events was accompanied by the occurrence of a typical occlusion phenomenon below the inguinal ligament.

In order to demonstrate the compression of the vein in another plane, the patient was turned through 45° and a film was obtained with the beam forming a tangent with the ileo-psoas muscle (Fig. 4); the compression and emptying of the external iliac vein was then more distinct. What really happens during the so-called occlusion phenomenon, is thus not simply a local compression of the vein distal to the inguinal ligament but a compression of the entire external

a b c

Fig. 5. a) Femoral vein without straining. b) Occlusion phenomenon during straining. c) Elimination of occlusion upon application of cuff around the thigh.

iliac vein in the lesser pelvis down to a level below the inguinal ligament, where the increased intra-abdominal pressure no longer makes itself felt. This compression cannot be due to femoral herniation. If it were, the veins would be compressed only at the level of the hernia in the femoral canal.

This assumption is also supported by the following observations. Thirty-seven patients exhibiting the occlusion phenomenon on retrograde femoral phlebography were examined by the following method. A cuff was placed around the thigh, about 20 cm below the inguinal ligament, and inflated to a pressure of about 150 mm Hg. The patients were then reexamined under conditions otherwise identical with those which caused the compression of the femoral vein; in no instance was the so-called occlusion phenomenon observed.

The phlebograms reproduced in Fig. 5 are from three examinations performed in succession on one and the same patient with the femoral vein without straining (a), the occlusion phenomenon during straining (b), and elimination of the phenomenon on application of a cuff around the thigh (c). This sequence of events is also supported by the investigation of BORGSTRÖM et coll. who found that it is not possible to control the compression phenomenon by femoral hernioplasty by the methods of BURTON or MCVAY.

It appears that the occlusion phenomenon can occur only if the leg veins are incompetent, i. e. if the flow can be reversed.

In Fig. 6a a schematic illustration is given of the lacuna vasorum showing

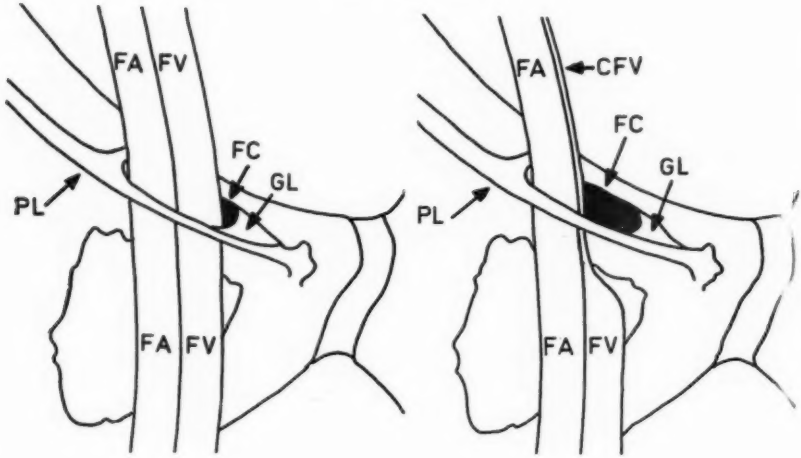

Fig. 6. Schematic illustration of lacuna vasorum. FA — Arteria femoralis, FV — Vena femoralis, PL — Ligamentum inguinale, GL — Ligamentum Gimbernati, FC — Canalis femoralis, CFV — Compressed vein.

the femoral artery and vein, the lacunae and the perivascular space with the area medial to the latter, between the vein and ligamentum Gimbernati, covered by a thin fibrous septum, Cloquet's septum, which consists of a continuation of the connective tissue sheath of the vessels, fascia transversa and the peritoneum. As stated previously, the femoral vein expands and fills the femoral canal during straining. This mechanism protects the vulnerable fibrous septum in the femoral canal from being affected by the increased intra-abdominal pressure during straining although, in patients with incompetence of the femoral vein and exhibiting the occlusion phenomenon, straining has the opposite effect on the femoral canal.

In Fig. 6b it is illustrated how the femoral canal increases markedly in width on occlusion of the vein in association with straining. The fibrous septum which occludes the femoral canal is now distended to such an extent as to reach from the ligamentum Gimbernati outwards to the medial wall of the artery, against which the vein is compressed.

It is generally recognized that the femoral canal is a common site of hernia of the abdominal wall, a locus minoris resistentiae. The femoral canal is nevertheless not a preformed but rather an acquired outlet (Dickson; Tashe; Wilmoth). There is also a clear correlation between femoral herniation and varices. Gullmo (1957) has demonstrated the occlusion phenomenon as such and its relation to venous incompetence; as we have shown, this occlusion

imp es severe trauma to a fibrous structure whose function is to close a her a outlet.

W ien femoral herniation and venous incompetence occur together, there app ars to be some justification in assuming that incompetence of the venous val s occurs first and that femoral herniation is a sequela; in other words, tha emoral herniation is due to venous incompetence. This point is receiving fur er attention.

SUMMARY

T e normal haemodynamics of the external iliac and femoral veins were investigated in 39 s jects and compared to those observed in the presence of valvular incompetence. Straining in n mal subjects appears to close a latent hernia outlet, while in the strain obstruction syndro e the outlet is opened. If femoral herniation and valvular incompetence occur in the sam patient, there is reason to assume that the incompetence is primary and a causal factor in the f rmer.

ZUSAMMENFASSUNG

Die normale Hämodynamik der Vena iliaca externa und der Vena femoralis wurde bei 39 Personen untersucht und mit der Hämodynamik verglichen, welche beim Vorliegen einer Klappeninsuffizienz beobachtet wird. Anspannung bei Normalpersonen scheint eine latente Bruchpforte zu verschliessen, während beim Spannungsobstruktionssyndrom die Pforte offen steht. Treten femorale Herniierung und Klappeninsuffizienz bei einem und demselben Patienten auf, ist man zu der Annahme berechtigt, dass die Insuffizienz das Primäre ist und als kausaler Faktor in dem Vorhergenannten wirkt.

RÉSUMÉ

L'auteur a étudié l'hémodynamique normale de la veine iliaque externe et de la veine fémorale chez 39 sujets et l'a comparée à l'hémodynamique dans les cas d'insuffisance valvulaire. Chez les sujets normaux, il semble que l'effort ferme un orifice herniaire latent, alors que dans le syndrome d'obstruction à l'effort, l'orifice est ouvert. Si un même malade présente une hernie crurale et une insuffisance valvulaire, il y a des raisons de supposer que l'insuffisance valvulaire est primitive et est un facteur causal de la hernie.

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FROM THE RADIATION PHYSICS DEPARTMENT (DIRECTOR: ASSOC. PROF. KURT LIDÉN), UNIVERSITY OF LUND, SWEDEN.

RADIATION BEHIND A GRID DURING ROENTGENOGRAPHY

by

BENGT BJÄRNGARD and GUNNAR HETTINGER

The radiation behind the patient during roentgenography is composed of photons coming directly from the focus (primary radiation) and photons that have undergone one or more Compton scatterings within the patient (scattered radiation). The purpose of using a grid is to absorb the scattered radiation which merely reduces the diagnostic usefulness of the roentgenogram.

The primary radiation transmitted through the patient can be calculated from published roentgen spectra (3). The spectral and angular distribution of the scattered radiation behind slabs of water, irradiated by photons with energies between 50 and 250 keV, was recently investigated (2). Starting from these spectra, one can calculate the filtering effect of a grid. However, a close analysis of the efficiency of a grid must include a study of the radiation generated in the grid itself. This grid radiation is composed of photons Compton scattered mainly in the interspacing material and of characteristic K-radiation generated when primary and scattered photons are photoelectrically absorbed in the lamellae.

Extensive experimental and theoretical studies have been made of the practical usefulness of different types of grids used in roentgenography (1, 4, 5, 6), but no experimental determination of the grid radiation has been carried out.

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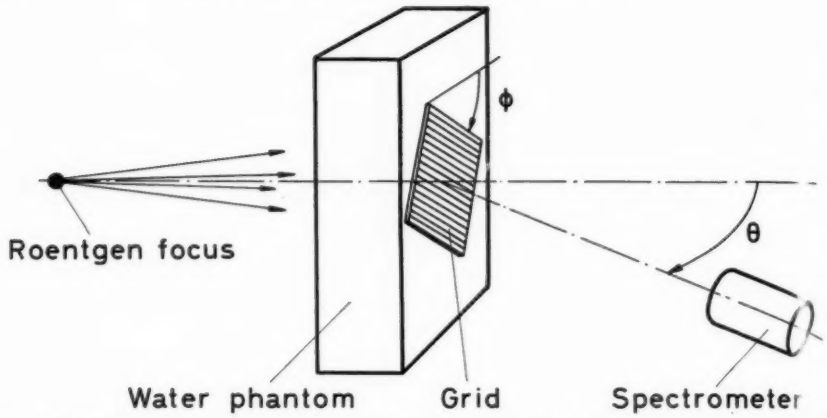

Fig. 1. Experimental arrangement for study of secondary radiation in different directions behind a grid. The direction is defined by the scattering angle Θ and the azimuth angle Φ.

In this investigation we measured spectra of the radiation behind a grid placed behind a water phantom. Spectra of the radiation scattered from the water and attenuated in the grid were calculated from distributions given in reference (2). These calculated spectra were compared with the measured ones, and from the deviations the quantity and quality of the grid radiation were estimated.

Experimental

The grid used in this experiment was light and non-focusing. It had 27.2 parallel lead lamellae per cm and aluminium interspacing. The thickness of a lead lamella was 0.05 mm and the height 1.7 mm. The ratio was 1 : 5.3 and the lead content 0.26 g per cm^2.

The experimental arrangement is shown in Fig. 1. The grid was placed immediately behind a parallelepipedical water phantom 15 cm thick and of an area of 30 × 30 cm^2. The distance between the source of radiation and the front of the phantom was 60 cm. The central ray was perpendicularly incident on the centre and the irradiated circular area on the grid was 200 cm^2. The radiation from the roentgen apparatus was heavily filtered and the mean energy of the primary photons was 116 keV. The spectrum had a full width of 60 keV at half maximum. Most of the primary photons and a great part of the photons scattered from the water phantom had energies above the K absorption edge of lead at 88 keV. This primary radiation makes the K-radiation from the lead lamellae more intense than a softer primary radiation of the diagnostic type.

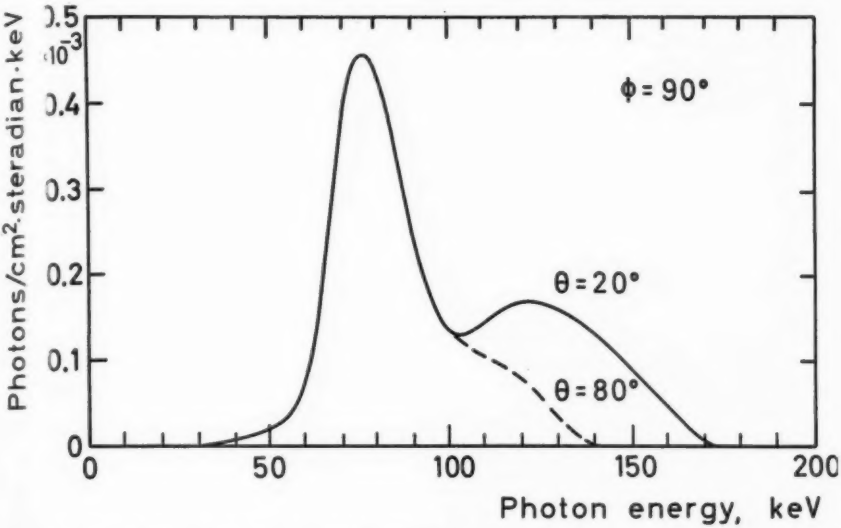

Fig. 2. Spectra of the grid radiation in two directions. No water phantom between roentgen focus and grid. Lead K-radiation (left peak) and Compton scattered radiation (right peak).

The secondary radiation in different directions behind the grid was studied with a NaI scintillation spectrometer. The crystal was provided with collimators so that it could 'see' only a small elliptical surface on the back of the grid. The short axis of this ellipse was 0.5 cm. The detector was rotated in a horizontal plane around an axis through the centre of the grid. The scattering angle Θ was measured from the central ray of the primary beam. Since the radiation behind the grid has no rotation symmetry, every scattering angle Θ had to be coordinated with an azimuth angle Φ (Fig. 1). A further description of the experimental procedure is given in another paper (2).

Some measurements were made with only the grid as a scatterer. The water phantom was then removed while the remainder of the experimental arrangement was unchanged.

Results and Discussion

Spectra of the radiation scattered in the directions $\Theta = 20°$, $\Phi = 90°$, and $\Theta = 80°$, $\Phi = 90°$, when the grid was irradiated without the water phantom in front of it, are shown in Fig. 2. The spectra correspond to photons scattered or generated in the grid itself. The distributions were not corrected for the resolution but it is evident that the low-energy peak corresponds to K-radiation from lead and that the upper part of the spectrum corresponds to Compton scat-

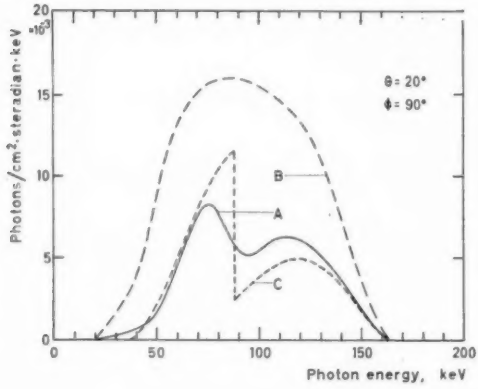

Fig. 3. Spectra of radiation in direction $\Theta = 20°$, $\Phi = 90°$ when the average primary flux leaving grid is one photon per cm². A: Measured spectrum behind grid; B: Radiation scattered from water phantom; C: The part of B transmitted through grid according to calculations.

tered photons. The maximum energy of the primary photons was about 170 keV. When Compton scattered 20° or 80°, the resulting photons acquire energies that agree well with the upper energy limits in Fig. 2. Most of the once-scattered photons have energies above the K-absorption edge of lead (88 keV). Any appreciable contribution from multiply-scattered photons to the low-energy peak is not probable, since the grid is thin. This low energy peak in the spectra has the same shape and height in all scattering angles Θ, while the upper part of the spectrum agrees with the laws of Compton scattering. The low energy peak is therefore almost entirely due to lead K-radiation, which has an average energy of 76 keV.

After a graphical integration over all directions Θ, Φ the composition of the grid radiation was estimated to be about 75 per cent lead K-radiation and 25 per cent Compton scattered radiation. The total spherical number flux of the grid radiation was 0.03 photons per cm², when the primary flux leaving the back of the grid was one photon per cm² averaged over the grid surface (Table, p. 382). The fractional number transmissions of the grid to primary photons were 0.00 behind the lead lamellae and 0.93 behind the aluminium. Thus the average number transmission of the grid was 0.80.

The solid curves (A) in Figs 3 and 4 show spectra of the scattered radiation behind the grid in the directions $\Theta = 20°$, $\Phi = 90°$, and $\Theta = 80°$, $\Phi = 90°$, respectively, when the grid was placed close behind the 15 cm thick water phantom. For comparison two more spectra are drawn in each diagram. The dashed curves (B) correspond to the scattered radiation leaving the water slab in the direction in question (2). The radiation transmitted by the grid is represented by the curves denoted with a C. These spectra are calculated from

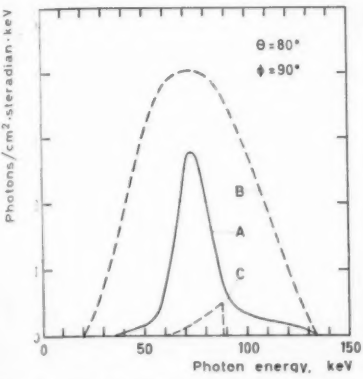

Fig. 4. Spectra of radiation in the direction $\Theta = 80°$, $\Phi = 90°$ when average primary flux leaving grid is one phantom per cm². A: Measured spectrum behind the grid; B: Radiation scattered from the water phantom; C: The part of B that is transmitted through the grid according to calculations. Difference between measured spectrum (A) and calculated (C) is due to grid radiation.

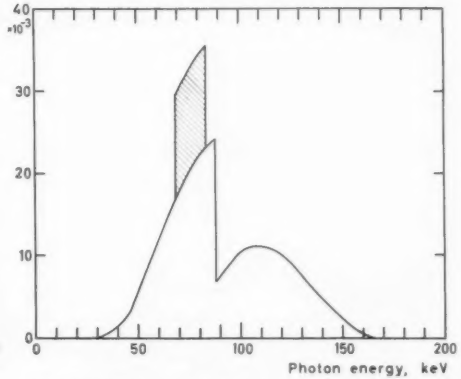

Fig. 5. Spectrum of the spherical flux of secondary radiation behind the grid. The K-radiation is represented as a bar and the Compton scattered component of the grid radiation is included in the upper part of the spectrum. One primary photon per cm² is on an average leaving the surface element observed. The average energy of the primary photons is 116 keV.

(B) and the attenuation factors used were calculated with regard to the geometry of the grid.

The discontinuity at 88 keV in the calculated spectra (C) is due to the absorption edge of lead. In the measured pulse height distributions (curves A) this discontinuity is smoothed out. In Fig. 3 there is a good agreement between the surfaces under the curves (A) and (C). The grid radiation is relatively unimportant in the direction $\Theta = 20°$, $\Phi = 90°$. This is not true in the direction $\Theta = 80°$, $\Phi = 90°$ (Fig. 4). The great difference between the measured and the calculated spectra (A and C, respectively) is caused by the grid radiation generated by the primary radiation and by the radiation scattered from the water phantom.

None of the spectra in Figs 3 and 4 was corrected for the resolution. Calculations have shown that no appreciable error is introduced in the surfaces of the curves when this correction is neglected. All the distributions are represented in absolute units.

When we integrate over all directions Θ, Φ, the spherical flux is obtained. Fig. 5 shows the spectrum of the spherical flux of the calculated transmitted radiation, to which the lead radiation was added as a bar with a width of 15 keV. The photons Compton scattered from the grid are included in the upper part of the spectrum. The number flux (the surface under the curve in Fig. 5)

Table

Spherical number flux of secondary radiation in photons per cm² when on an average one primary photon per cm² leaves the small surface under observation

Primary radiation	Surface of observation was behind	Number flux of secondary radiation			
		Grid radiation due to		Scattered radiation originating from the water (photons/cm²)	Total (photons/cm²)
		Lead K-radiation (photons/cm²)	Compton scattering in the grid (photons/cm²)		
$(E)_{average} = 116$ keV	Grid alone	0.02	0.01	—	0.03
$(E)_{average} = 116$ keV	15 cm water	—	—	3.00	3.00
$(E)_{average} = 116$ keV	Grid behind 15 cm water	0.19	0.06	1.10	1.35
170 kV radiation HVL = 0.4 mm Cu	15 cm water	—	—	3.00	3.00
170 kV radiation HVL = 0.4 mm Cu	Grid behind 15 cm water	0.06	0.06	1.02	1.14

is 1.35 photons per cm² when on the average one primary photon per cm² is leaving the small surface under observation. About 20 % of these 1.35 photons is due to grid radiation, mainly as K-radiation from lead (see table, above). Without the grid the number flux in the centre of the back of the water slab would have been 3.0 photons per cm² per unit primary flux (2). Thus the grid has reduced the build-up considerably by absorbing some of the photons scattered from the water. However, this reduction in the number of secondary photons has been counteracted to some extent by the grid itself, when generating its grid radiation as seen in the table.

If the energy of the primary radiation is decreased, it can be expected that the contribution from grid radiation decreases. The K-radiation component disappears when the photon energy is below the K-absorption edge. On the other hand, it is probable that the number flux of photons Compton scattered from the grid is approximately independent of the photon energy. Other experiments have verified this behaviour for photons scattered from water slabs (2).

As an application of the results of this experiment, we calculated the grid radiation when the water phantom and the grid were irradiated by a roentgen apparatus with 170 kV constant potential and a total filtration of 4 mm aluminium. The spectrum of this primary radiation was taken from reference (3). The primary spectrum was divided into two parts, one of which was identical to the spectrum of the primary radiation used in this experiment. The other component had very few photons with energies above 88 keV. The K-radiation

fro lead is consequently determined by the component with the higher energy, wh e the build-up of photons Compton scattered from the grid was assumed to e energy independent. The scattered radiation behind the water slab was cal ılated from the spectral distributions of reference (2) and then corrected for he attenuation in the grid.

he results are included in the bottom line of the table. As can be seen, the grid reduces the spherical number flux by about a factor of three. The gri radiation amounts to about 10 per cent of the total flux of secondary rac ation originating from this primary radiation of the diagnostic type. It ca be expected that the grid radiation is more important when the opening rat of the grid is decreased and less when the number of electrons per cm² of e interspacing material is decreased. Though not of the utmost importance, it i obvious that the grid radiation cannot be neglected when constructing grids giv ng an optimum image quality.

he errors in the data presented in the table were estimated. The values for the number flux of the grid radiation are particularly uncertain. Calculations sho ed that the limits of error were about — 10 and + 50 per cent.

Acknowledgements

The authors wish to express their sincere thanks to K. Lidén and C. Carlsson for their valuable suggestions.

SUMMARY

The composition of the radiation behind a diagnostic grid was studied with a scintillation spectrometer. The quantity and quality of the secondary radiation generated in the grid was estimated. In a practical case the grid radiation amounted to about 10 per cent of the secondary radiation behind the grid.

ZUSAMMENFASSUNG

Die Zusammensetzung der Strahlung hinter einem Streustrahlenraster wurde mit einem Szintillationsspektrometer studiert. Die Quantität und die Qualität der im Raster erzeugten Streustrahlung wurde beurteilt. In einem aktuellen Fall fand man, dass die Rasterstrahlung etwa 10 % der hinter einem Raster vorkommenden Streustrahlung ausmacht.

RÉSUMÉ

Les auteurs ont étudié au moyen d'un spectromètre à scintillations la composition du rayonnement derrière une grille de diagnostic. Ils ont évalué la quantité et la qualité du rayonnement secondaire engendré par la grille. Dans un cas pratique, le rayonnement de grille s'élève à environ dix pour cent du rayonnement secondaire derrière la grille.

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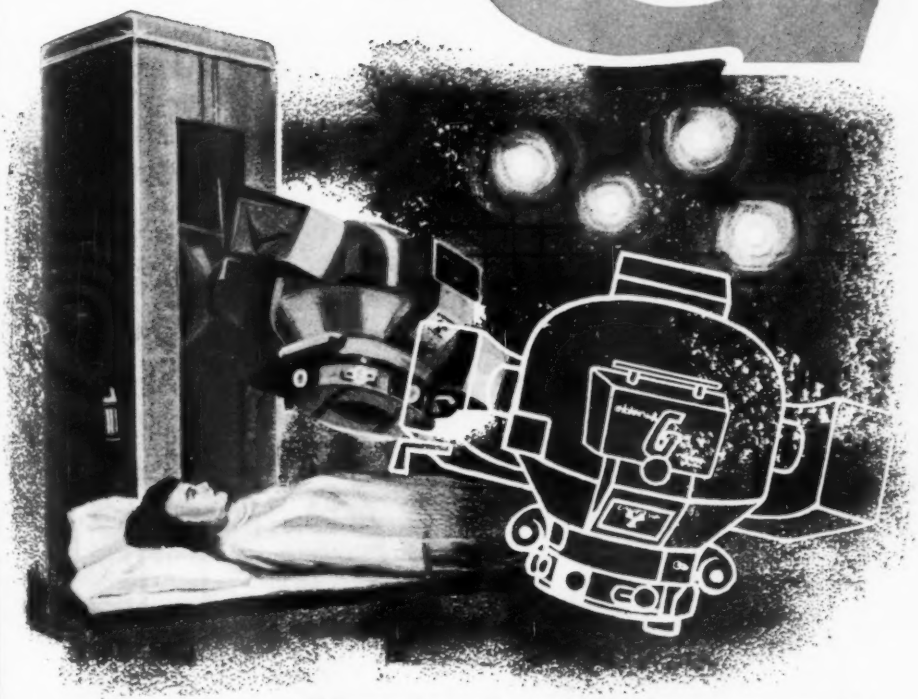

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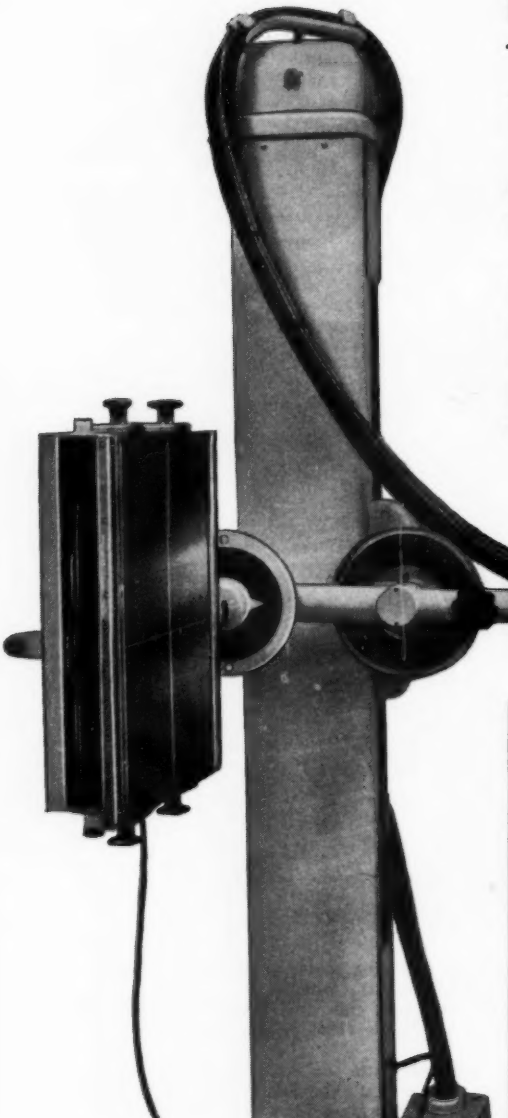

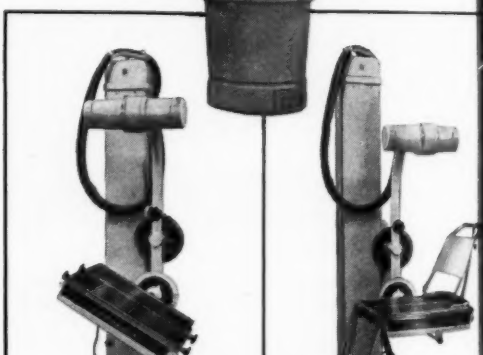

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FROM THE GYNECOLOGIC DEPARTMENT (DIRECTOR: G. GORTON) OF THE KONUNG GUSTAF V JUBILEUMSKLINIK, LUND, SWEDEN.

MALIGNANT NEOPLASMS OF THE VULVA

by

JOHN-ERIK JOHNSSON

Malignant tumours of the vulva are relatively rare and are believed to represent only 2 to 10 % of all growths of the female genital tract; they occur mainly in elderly women between the ages of 60 and 70 years. The results of treatment have not been found to be very encouraging though the primary seat of such tumours as well as the regional lymph nodes are readily accessible to radical surgery.

Material. The present material consists of 175 cases admitted to hospital during the period 1947—1959 for neoplasms of the vulva. These represented 4.2 % of all cases of cancer of the female genital tract admitted during those years. The age distribution in the material was as follows: 9 patients were between 31—40 years of age (5.2 %), 17 between 41—50 years (9.8 %), 24 between 51—60 years (13.7 %), 52 between 61—70 years (29.7 %), 50 between 71—80 years (28.6 %), 22 between 81—90 years (12.5 %) and one patient, finally, 91 years of age (0.5 %); thus 71 % of the patients were over 60 and 41 % over 70 years of age.

It is usually itching, a sore, or the detection of a small nodule in the vulva that causes the patient to seek advice. Sometimes, though rarely, the condition is ushered in by bleeding, vaginal discharge or difficulty in micturition; it should however be observed that the initial symptom in growths of the clitoris is often a sensation of burning on micturition. Eighty-one per cent of the patients

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had reported a sore, and/or nodule and/or pruritus as the first sympt n; pain also occurred in advanced cases. Pruritus, which is one of the predomin nt symptoms, is also a cardinal symptom of other conditions of the vulva s ch as kraurosis and leukoplakia; the number of cases in which kraurosis nd leukoplakia precede or accompany the appearance of cancer of the vulva va ies widely from one series to another (13 to 75 %, SCHÖMIG et coll. 1950, MÖ tus 1951) probably because the skin changes are not always noted. In the pre nt material such cutaneous changes were present in 33 % of the cases.

The tumours usually arise in the labium majus or labium minus, less re-quently in the clitoris or posterior commissure. The tumour was situated in the labium majus or labium minus in 138 cases, in the clitoris in 28, and in the posterior commissure in 9 cases. Tumours of the vulva are classified into groups and stages according to their appearance, local spread, and the presence or absence of clinical metastases. This classification is not uniform and varies from one hospital to another and from examiner to examiner. BERVEN (1941) classified tumours of the vulva as follows:

Group I Non-ulcerated tumour localized to the (a) labium majus and minus, (b) clitoris, (c) posterior commissure;

Group II Ulcerated tumour of same spread as in group I;

Group III Tumour involving more than one of the three above-mentioned sites;

Group IV Tumour infiltrating contiguous tissue (vagina, perineum, urethra, genito-femoral fossa).

Stage I Without clinical metastases in inguinal lymph nodes;

Stage II Probable involvement of still movable inguinal lymph nodes;

Stage III Probable involvement of inguinal lymph nodes fixed to contiguous tissue.

Most of the malignant vulvar tumours are of the squamous cell variety (80 to 90 %), the remainder consisting of adenocarcinomas, basal cell carcinomas, malignant melanomas and malignant hydradenomas. The present material comprised 158 cases of squamous cell carcinoma, 10 of malignant melanoma, 4 of basal cell carcinoma, 1 of adenocarcinoma, 1 of low-differentiated carcinoma and 1 case of sarcoma. The tumours grow fairly rapidly in the loose subcutaneous tissue of the vulva and soon spread to the local lymph nodes. Forty-five per cent of the patients had had symptoms for six months or less, and 34 % for more than one year. About half of all the patients had metastases in one or both groins on admission (Tables 1 and 2).

Table 1

Case material (1947—1959) grouped according to local extent of involvement

	Number of patients	Number of patients operated upon
Group I	39 (22.3 %)	38
Group II	87 (49.6 %)	84
Group III	45 (25.8 %)	41
Group IV	4 (2.3 %)	3
Total 175		166 (95 %)

Table 2

Case material grouped in stages according to absence or presence of metastases 1947—1959

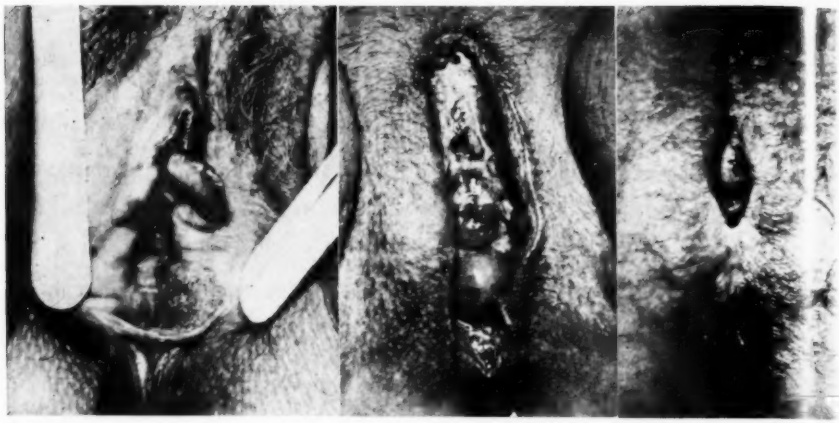
	Number of patients	Number of patients operated upon
Stage I	95 (54.5 %)	94
Stage II	52 (29.6 %)	52
Stage III	28 (15.9 %)	20
Total 175		166 (95 %)

Treatment and Results

In many hospitals treatment is still only by surgical operation with more or less radical extirpation of the tumour as well as of the inguinal lymph nodes on one or both sides, sometimes with removal of the pelvic lymph nodes. The results have not proved encouraging. Five-year cure rates of 30 to 45 % have been reported, but the figures are usually lower (TAUSSIG 1940, KOTEK 1949, ISTRE 1951, CASSIDY 1957).

The survival rate of patients who received radiotherapy only was originally even lower (11 to 12 %) though it was later improved (26 %) by the use of special techniques. Recurrences appear to be more common (KOTEK 1949, TODD 1949, ELLIS 1949, MÖBIUS 1951, HUBER 1953). Combined surgical and radiation therapy has also not given a 5-year cure rate of more than 25 to 38 % (BERVEN, KOTEK).

The results obtained in two recent series are however more promising. Thus STENNING & ELLIOT (1959) reported a 5-year cure rate of 60 % in patients with vulvar carcinoma of the squamous cell variety only, and WAY (1960) gave a corresponding rate of 61 % and 49 % in two series of 79 and 96 cases, respectively. Treatment consisted of radical excision of the vulva and bilateral removal of the regional (inguinal and pelvic) lymph nodes.



a b c

Cancer of the vulva (a), at ten days after electrocoagulation (b), and when the vulva had healed (c).

Combined surgical and radiation therapy has been our rule since 1947. The surgical part of the treatment consists of radical electrocoagulation of the entire vulva as described by BERVEN. In cases in stage I (no clinical metastases in inguinal lymph nodes) the surgical treatment is limited to this procedure. A moderate dose of telegamma or roentgen rays is given to the inguinal lymph nodes. In stages II and III (with involvement of the lymph nodes) treatment is extended to include irradiation and subsequent removal of the inguinal lymph nodes on the side(s) involved. If operation reveals gross signs of involvement of the pelvic lymph nodes, they are also removed.

Of the 175 patients 5 were very old and in a poor general condition and had advanced tumours; 3 of these received no treatment and 2 palliative treatment only. Four others had been operated upon elsewhere and had been referred to the department for postoperative irradiation of the inguinal lymph nodes. The remaining 166 cases (95 %) were treated in the way outlined above. Electrocoagulation of the vulva was performed in all of the cases except two. The postoperative complications were few. Two patients died within 2 weeks of operation (pulmonary embolism and cerebral haemorrhage). In one patient bleeding from the wound was so profuse as to cause a fall in blood pressure. In 9 cases (5.5 %) the body temperature was at least 39° C for more than 48

hours after the operation. In 7 cases radical removal of the tumour required excision of the anal region with the sphincter and the lower part of the rectum after transversostomy. One patient died from peritonitis complicating colostomy prior to planned radical electrocoagulation.

Twenty-three (14 %) of the cases treated with electrocoagulation had local recurrences. In one case bilateral ureterosigmoidostomy was done because of severe urethral stricture. Moderate stricture of the urethra developed in one case. In another case the pudendal nerve was divided on both sides because of persistent intense pruritus after the vulva had healed and in still another case division of the nerve was also considered, but was postponed because the itching abated. The operation was followed by stenosis of the introitus of the vagina in 7 and by prolapse in 4 cases.

In 73 (41.5 %) of the cases the inguinal lymph nodes were excised and in 27 the pelvic lymph nodes also were excised. In 2 of them the vulvar tumour had been radically excised at another hospital. For such a major operation on these relatively old patients the frequency of complications was low. The operative mortality (within 2 weeks of operation) consisted of one death from acute heart failure on induction of anaesthesia and in four cases the postoperative course was complicated by bleeding from the wound.

Excision of the inguinal and/or pelvic lymph nodes was followed by ipsilateral or bilateral leg oedema in 46.5 % of cases. Such swelling did not appear to be more common among those with microscopically verified involvement of the lymph nodes, but the series was not large enough to permit any valid conclusions. The symptoms after operation were slight or insignificant except in those cases in which the growth had invaded the perinodular fatty tissue, when they were severe. In 2 cases inguinal hernia occurred after the operation.

All of the 10 cases of malignant melanoma were treated with electrocoagulation and in 6 of them treatment was extended to include excision of the lymph nodes. Two of these cases are now symptom-free six years, and six months, respectively, after the operation. One has survived two and a half years but has symptoms of remote metastases. The remaining 7 patients died from remote metastases (lungs, skeleton, liver) two months to one year after the operation. The two patients with sarcoma and low-differentiated carcinoma, respectively, have died from their diseases. The four patients with basal cell carcinoma are still alive with no signs of recurrence; in one of them a local recurrence however developed but the patient is now symptom-free (follow-up: 5 years).

The 5-year cure rate may be assessed on the basis of 102 cases (93 of squamous cell carcinoma, 6 of malignant melanoma, 2 of basal cell carcinoma and 1 case of sarcoma) treated in 1947—1954. Of these, 97 cases (95 %) were treated in the way described above and 52 patients (51 %) are still alive and symptom-free more than 5 years after the operation. Of these 52 patients however, 4 have had local recurrences 5 years after the first operation. These recurrences have been treated with electrocoagulation.

Table 3

Cases grouped in stages according to absence or presence of metastases during the period 1947—1954

	Number of patients	Number of patients operated upon	Symptom-free for at least 5 years	
Stage I	48 (47 %)	47	29	(60 %)
Stage II	36 (35.3 %)	35	17	(42.5 %)
Stage III	18 (17.7 %)	15	6	
Total	102	97 (95 %)	52	(51 %)

As expected, the prognosis of stage I, i. e. patients without clinical involvement of the local lymph nodes, is much better than that of stages II and III. As known, palpation cannot always indicate whether a lymph node is involved or not. According to BERVEN, about 20 % of patients are erroneously classified as stage I. If this were so in the present series, it would mean that by no means all the lymph nodes involved were excised. An attempt was therefore made to clarify this point and decide whether it might be of prognostic significance.

During the period 1947—1954 a total of 48 cases were classified as stage I. Of these, involvement of the lymph nodes was later diagnosed in eleven. Microscopic examination showed evidence of cancer in all of them. The follow-up in all these cases is still less than 5 years. In 9 cases the tumour continued to grow in the perinodular fatty tissue.

In the entire material (1947—1959) a total of 95 cases were classified as stage I. In 23 of these (24 %), metastases to the lymph nodes were diagnosed later and verified histologically. Two other patients also have metastases, but the condition of these is such that operation is not being considered.

Discussion

A series of 175 cases of malignant vulvar neoplasms treated during the period 1947—1959 was analysed. The age distribution, the site, and the microscopic appearance of the tumours were largely the same as in other series. It would appear from the Anglo-American literature that there is an increasing tendency to treat the disease surgically with radical removal of the tumour and, unless contra-indicated by the patient's general condition, excision of the local lymph nodes, preferably as a single stage operation. With this method a 5-year cure rate of about 60 % has been reported in a few series. The patients in the present material had been treated in this way with radical coagulation of the vulva in 95 % and excision of the local lymph nodes in 41.5 % of the 175 cases. In addition the sites of the lymph nodes were treated radiologically. Of 102 patients (1947—1954), 51 % were still alive and symptom-free after 5 years.

The investigation also showed the extremely poor prognosis of malignant melanoma compared with that of basal cell carcinoma despite occasional local recurrences of the latter.

Metastases occurred in local lymph nodes in about a quarter of the cases in which no such involvement could be detected before operation. These metastases appeared fairly soon after operation and excision was then difficult. In addition most of these cases were not symptom-free after the operation. The follow-up in all these cases is still less than 5 years. Since excision of the lymph nodes carries such a very low mortality, it would appear wise to extend treatment to include bilateral excision of the local lymph nodes as a routine measure in all cases in which this is possible and not contra-indicated by the general condition.

SUMMARY

A series of 175 cases of malignant vulvar neoplasms, 95 % of which had been treated with radical electrocoagulation of the vulva, was analysed. The local lymph nodes had been excised in 41.5 % of the cases. In addition the sites of the lymph nodes had been treated radiologically. A 5-year cure rate of 51 % is reported.

ZUSAMMENFASSUNG

Ein Material von 175 Fällen mit malignen Vulvatumoren wurde analysiert, von denen 95 % mit radikaler Elektrokoagulation der Vulva behandelt worden waren. Die lokalen Lymphdrüsen waren in 41.5 % der Fälle exzidiert. Das Lymphdrüsengebiet war zusätzlich radiologisch behandelt worden. Eine 5-Jahres-Heilung von 51 % wird berichtet.

RÉSUMÉ

L'auteur a étudié une série de 175 cas de cancer de la vulve, dont 95 % avaient eté traités par électrocoagulation radicale de la vulve. Les ganglions lymphatiques locaux avaient été enlevés dans 41.5 % des cas. De plus, l'emplacement des ganglions lymphatiques avait été traité par radiothérapie. Un taux de guérison de 5 ans de 51 % a été obtenu.

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RADIOPROTECTIVE EFFICACY OF CYSTEAMINE WITH THE MITOTIC INDEX OF RAT BONE MARROW CELLS AS REFERENCE SYSTEM

by

P. DE, A. BOSE and S. BOSE

The present work is concerned with the protective efficacy of a given dose (150 mg/kg bodyweight) of cysteamine against a lethal dose (800r) of irradiation during a period of from zero hours to 30 days after irradiation with the mitotic index of rat bone marrow cells as a common biologic reference system. The radioprotective efficacy of cysteamine (β-mercaptoethylamine) in varying doses has been previously assessed in different species of animals at different intervals after irradiation also in varying doses (BACQ et coll. 1953, GROS et coll. 1953, GEREBTZOFF et coll. 1954, DEVIK et coll. 1955, MAISIN et coll. 1955, ARMELLINI et coll. 1958, FUMAGALLI et coll. 1958, CHATTERJEE et coll. 1959, and RAY-CHAUDHURI 1961).

Material and Method. The irradiation, tissue collection, fixation, histologic preparations and scoring of data were performed as reported previously (DE et coll. 1960). The protective agent, cysteamine 150 mg/kg bodyweight, was administered intraperitoneally to protected groups of animals immediately before irradiation.

A total of 240 rats formed the material in this set of experiments. In the early investigation, as described in Table 1 (from 5 minutes to 24 hours after irradiation), 135 rats were divided equally into three groups and from each group, 3

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Table 1

Correlation of the radioprotective efficacy of 150 mg/kg cysteamine with the mitotic index of rat bone marrow cells irradiated with 800 r

Time interval	Mitotic index %			1st protective index $\left(\frac{P-R}{N-R} \times \times 100\right)$	2nd protective index $\left(\frac{P}{N} \times 100\right)$	Value of 't' between (N and P)	Significance
	Normal control (N)	Irradiated control (R)	Protected series (P)				
5 min	1.39 ±.085	0.92 ±.106	1.07 ±.110	31 %	77 %	9.1	5 % &
½ hr	1.41 ±.096	0.17 ±.084	0.24 ±.071	6 %	17 %	39.0	»
1st hr	1.39 ±.095	0.20 ±.046	0.22 ± 070	2 %	16 %	39.1	»
2nd hr	1.39 ±.100	0.21 ±.080	0.23 ±.096	2 %	17 %	33.1	»
3rd hr	1.40 ±.107	0.22 ±.075	0.24 ±.071	2 %	17 %	36.2	»
4th hr	1.42 ±.078	0.26 ±.074	0.27 ±.088	1 %	19 %	38.3	»
5th hr	1.39 ±.097	0.30 ±.096	0.32 ±.099	2 %	23 %	30.5	»
6th hr	1.41 ±.095	0.26 ±.066	0.37 ±.089	10 %	26 %	31.5	»
7th hr	1.42 ±.103	0.20 ±.060	0.38 ±.084	15 %	27 %	30.5	»
8th hr	1.40 ±.077	0 21 ±.066	0.43 ±.063	18 %	31 %	37.3	»
9th hr	1.39 ±.094	0.23 ±.082	0.44 ±.075	18 %	32 %	30.6	»
12th hr	1.40 ±.085	0.72 ±.084	0.84 ±.080	17 %	60 %	19.3	»
15th hr	1.41 ±.087	0.67 ±.093	0.77 ±.096	14 %	55 %	19.4	»
18th hr	1.39 ±.089	0.43 ±.060	0.72 ±.096	30 %	52 %	20.3	»
21st hr	1.40 ±.100	0.34 ±.095	0.68 ±.054	32 %	49 %	24.8	»
24th hr	1.38 ±.093	0.27 ±.089	0.65 ±.092	34 %	47 %	22.1	»

rats were assessed in each period. In the periods of late investigation (1st day to 30th day after irradiation), 90 rats were selected and arranged in three groups, with an equal number of rats in each group. The assessment, as described in Table 2, was performed in 3 rats from each group for each period. Unprotected irradiated rats did not survive beyond 12 days.

Table 2

Correlation of the radioprotective efficacy of 150 mg/kg cysteamine with the mitotic index of rat bone marrow cells irradiated with 800 r

Time interval	Mitotic index %			1st protective index $\left(\frac{P-R}{N-R} \times \times 100\right)$	2nd protective index $\left(\frac{P}{N} \times 100\right)$	Value of 't' between (N and P)	Significance at
	Normal control (N)	Irradiated control (R)	Protected series (P)				
1st day	1.38 ±.093	0.27 ±.089	0.65 ±.092	34 %	47 %	22.1	5 % & 1 %
3rd day	1.40 ±.094	0.32 ±.090	0.79 ±.096	44 %	56 %	17.9	»
6th day	1.39 ±.080	0.36 ±.089	0.92 ±.093	54 %	66 %	15.1	»
10th day	1.39 ±.062	0.52 ±.093	0.63 ±.060	13 %	45 %	33.0	»
12th day	1.41 ±.092	2.02 ±.124	0.82 ±.084		58 %	19.0	»
15th day	1.42 ±.096	Dead	1.21 ±.075		85 %	6.1	»
18th day	1.40 ±.100	»	1.21 ±.080		86 %	5.9	»
24th day	1.40 ± 097	»	1.29 ±.094		92 %	3.23	»
30th day	1.42 ±.094	»	1.27 ±.099		89 %	4.28	»

Results

The recording of data proved to be difficult due to death of all the unprotected irradiated animals within twelve days following irradiation. The protective index has previously been indicated by the formula:

$$\frac{P-R}{N-R} \times 100$$

where N is the mitotic index of bone marrow cells of a normal series, R that of an irradiated (unprotected) series and P that of an irradiated but protected series. The formula showed the protection as a percentage of the total damage. In absence of R after a certain period in the present series, another criterion showing the mitotic index in protected animals as a percentage mitotic index in normal animals $\left(\frac{P}{N} \times 100\right)$ was taken into consideration. This naturally cannot be regarded as an index of protection but will certainly throw some light on

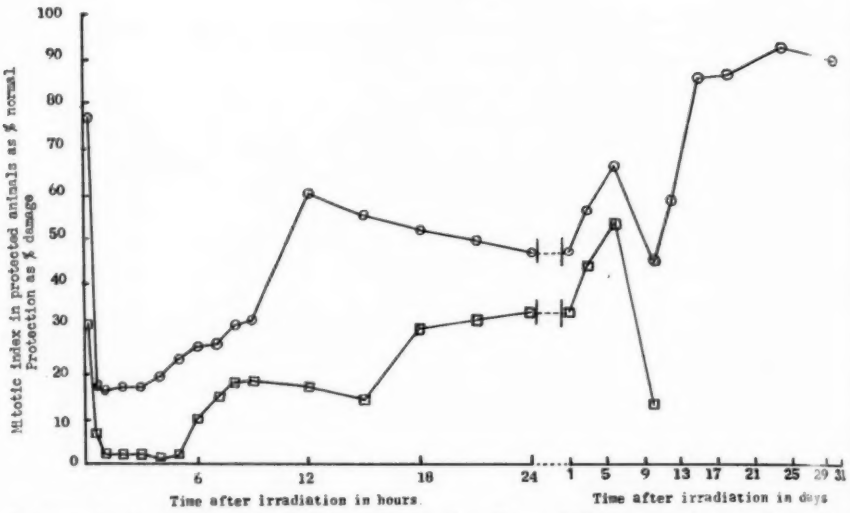

Diagram showing the assessment of the radioprotective efficacy of 150 mg dose of cysteamine per kg bodyweight, from 5 minutes to 30 days after 800r irradiation with the mitotic index as the reference system. The maximum stable protection (85 to 92 per cent) was reached between the 15th and 30th days.

○———○ Mitotic index in protected animals shown as ·/. normal $\left(\frac{P}{N} \times 100\right)$

□———□ Protection shown as ·/. damage $\left(\frac{P-R}{N-R} \times 100\right)$

the process of recovery in protected animals. Both these indices are included in the diagram above. The data of the period from 5 minutes to 24 hours after irradiation with the first and second indices have been included in Table 1 and the period from 1 day to 30 days following irradiation in Table 2.

Discussion

The reference system employed represents the growth manifestations of haemopoietic cells. These cells are also highly radiosensitive (BLOOM 1948).

The mitotic indices of the protected animals varied from 85 to 92 per cent of that of the normal controls between the 15th and the 30th day after irradiation. The protected animals appeared to have fully recovered from the effects of radiation by the 15th day. Maximum radiation damage was observed during the 10—12 days period as all the unprotected irradiated animals had died by this time.

RAY-CHAUDHURI reported that cysteamine affords definite, though partial, protection against radiation-induced (120r) chromosomal damage in the grass-

hc per. BACQ et coll. studied the radioprotective efficacy of cysteamine (3 m animal) in mice with whole body radiation doses of 700r and 900r em-pl ying different biologic reference systems (survival index, peripheral leuko-cy count, bodyweight). The results obtained in the present study are in agree-m nt with BACQ's results. Partial protection was observed in this laboratory in th assessment of the protective efficacy of sodium cyanide (1.5 mg/kg and 3 m kg bodyweight) against 800r on rat bone marrow cells. More perfect pro-te ion was afforded on the same biologic reference system against the same ra iation dose in the present investigation with cysteamine.

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We wish to express our deepest thanks to Prof. S. Mitra for his support and interest in this in estigation. Thanks are also due to Mr R. Chatterjee, Mr K. Bhattacharya, Dr S. K. Brahma an Dr S. Mondal for their suggestions and active cooperation.

SUMMARY

The protective efficacy of cysteamine (150 mg/kg bodyweight) was tested on rat bone marrow cells in vivo with the mitotic index as the biologic reference system during a period from 5 minutes to 30 days after 800r irradiation. Maximum stable protective efficacy (85 to 92 % of that of the normal controls) was observed between the 15th and 30th days.

ZUSAMMENFASSUNG

Die strahlenschützende Wirkung von Cysteamin (150 mgm/Kg Körpergewicht) wurde an Knochenmarkzellen von Ratten in vivo mit dem mitotischen Index als biologisches Referenzsystem während eines Zeitraumes von 5 Minuten bis 30 Tage nach Bestrahlung mit 800r untersucht. Maximale dauerhafte Schutzwirkung (85 bis 92 % der normalen Kontrollen) wurde zwischen dem 15. und 30. Tag nach der Strahlung beobachtet.

RÉSUMÉ

Les auteurs ont testé in vivo l'efficacité radioprotectrice de la cystéamine sur des cellules de moelle osseuse de rats. Ils ont utilisé comme système de reference biologique l'indice mitotique, sur une période allant de 5 minutes à 30 jours après une irradiation de 800r. L'efficacité protectrice stable maximale (85 à 92 % de celle des témoins normaux) a été observée entre les quinzième et trentième jours.

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BOOK REVIEWS

VELOPHARYNGEAL FUNCTION IN CONNECTED SPEECH. STUDIES USING TOMOGRAPHY AND CINERADIOGRAPHY SYNCHRONIZED WITH SPEECH SPECTROGRAPHY. By Lars Björk. 94 pages, 42 illustrations and 13 tables. Acta radiol. (1961) Suppl. No. 202. Price: Sw. Kr. 25.

Methods have been developed for high speed cineradiographic studies of the speech organs during connected speech using a roentgen image amplifier, a 35 mm film camera, and a high fidelity tape recorder for the sound. The speech has been analysed according to the visible speech method by means of a special 48-channel sound spectrometer constructed by H. Sund. It is possible to obtain visible recordings of any length of speech desired. A special device synchronizes each frame of the roentgen cinefilm with the sound.

For acoustic calculations of nasality it is of great importance to have accurate information regarding the cross-sectional area of the coupling between the nasal and oral cavities; this area can be reproduced with relative accuracy during the articulation of single sustained sounds by means of transversal tomography. The cross-sectional area was found to be mainly elliptical and to be a linear function of its sagittal major axis; the length of the latter can be obtained not only from a transversal tomogram but also from a lateral roentgen film of the velopharyngeal region. It is possible in this way to follow the variations in size of the coupling area between the nasal and oral cavities during connected speech.

Cineradiographic and sound-spectrographic studies of the movements of the soft palate, while four test sentences were being read, were performed in adult men and women and in children aged 6—8 years. The soft palate largely followed a fairly constant pattern of movements during the pronunciation of these sentences.

In normal speech the mean duration of the velum movements from the closed to open state are of the order of 130 msec and the opposite transition, i. e., closure, occupies about 160 msec. The speed of the velum movements does not change proportionally to the overall speaking rate but tends to be less variable. In low, normal and high speaking rates corresponding to overall durations of 100—200—300, respectively, on a relative scale, the velum movements were found to vary in the proportions 100—130—160. The assimilated nasality on both sides of a nasal consonant in connected speech affects a larger part of the speech before the nasal consonant than after the nasal consonant. Even unvoiced stops and fricatives may be affected to some extent without serious effects on speech quality as judged by trained listeners. The effect of slight nasalization as in normal speech in segments close to nasal consonants is primarily the reduction of the first formant level against other formants. The typical velopharyngeal coupling area is of the order of 60 mm². The effect of an extremely large degree of nasalization, in which the velum may approach the back of the tongue and the velopharyngeal coupling area is of the order of 250 mm², is a lowering of the frequency of the first formant (nasal resonance) and a relative decrease of the levels of the second and the third formants. Further closure of the nostrils causes an increase in the level of the first formant (low frequency resonance).

The results mentioned may be considered examples of the utility of the method for continuous studies of the physiologic changes in the speech organs in relation to the connected speech produced. The synchronizing device may of course also be used for synchronizing recordings of ECG, blood pressure, etc, with high speed roentgen cinefilms.

Autoreview

DAS CARCINOMA COLLI UTERI. SEINE PROGNOSE UND BEHANDLUNG MIT BESONDERER BERÜCKSICHTIGUNG DER STRAHLENTHERAPIE. Von Wilhelmine Janisch-Raskovic. 649 Seiten mit 76 Abbildungen und 69 Tabellen. Georg Thieme, Leipzig 1961. DM 75.

This comprehensive monograph is based on a study of 2 704 cases of cervical carcinoma treated from 1927 to 1948. Around a core of abundant information derived from a painstaking analysis of the hospital records of these cases the author presents a broad survey of the changing concepts and approaches to the therapy of cervical carcinoma in this century. The author takes as her starting point the contributions of Wertheim to the surgical treatment of this disease. The introduction and refinement of radiotherapy of cervical carcinoma are discussed in detail. An account is also given of the renaissance of the surgical approach in several European and American centres, including the ultraradical technique of Brunschwig and others.

The Chemnitz Gynaecologic Clinic, where the investigation was carried out is an institution devoted to the radiotherapeutic treatment of carcinoma of the cervix. A certain number of cases, to be exact 9.2 per cent, have, however, been subjected to surgery, mostly combined with radiotherapy. The operations were in most cases performed according to Wertheim. No hard and fast indications for surgery are laid down but there seems to be a tendency in this clinic to operate upon very early cases of squamous cell carcinoma, adenocarcinoma of the cervix, and cervical carcinoma associated with pregnancy.

Most of the cases were treated with radiotherapy. The technique adopted is a slight modification of the Stockholm method with fractionated radium treatment and roentgen therapy. Considerable attention is devoted to the question of the treatment of cervical carcinoma stage 0 which at the author's clinic is treated in the same manner as invasive carcinoma.

The results of the various treatments are presented in considerable detail. Indications and contra-indications, complications of treatment, routes and frequency of metastases, as well as survival rates and the way in which they are influenced by various factors are discussed in detail. It is no exaggeration to say that the penetration and analysis of the case material are exemplary.

One of the chief merits of the book lies in the discussion based upon detailed studies of the literature which the author gives to her own case material. Every aspect of the pathology, clinical picture and therapy of cervical carcinoma is surveyed with impressive knowledge and considerable erudition. Thus the various phases in the development of the surgical therapy of carcinoma of the cervix are considered in detail together with the pros and cons of vaginal and abdominal methods. There is also a broad description of the main principles of the various important radiotherapeutic centres (Paris, Stockholm, Heidelberg, München and Manchester). Complications arising in connection with the surgical and radiotherapeutic treatment are closely analysed and related to important etiologic factors. Different opinions on the treatment of cervical carcinoma in physiologic (pregnancy) and pathologic conditions are reported.

In this comprehensive book, in which for example even such relatively border questions as anaesthesia, prophylaxis and therapy in cases of thrombosis and embolism are discussed at length, the reviewer was, however, rather disappointed not to find at least a short chapter on the diagnosis of cervical carcinoma, especially with reference to the methods of colposcopy and cytodiagnosis now generally applied. It is also surprising that the author completely omits the Grahams' investigations of the radiation response, even if this method of examination has not been incorporated into the diagnostic arsenal at the Chemnitz clinic.

The work would have gained appreciably if the typography had been less cramped and unfortunately the list of errata given in the book might be considerably extended.

Sam Leody